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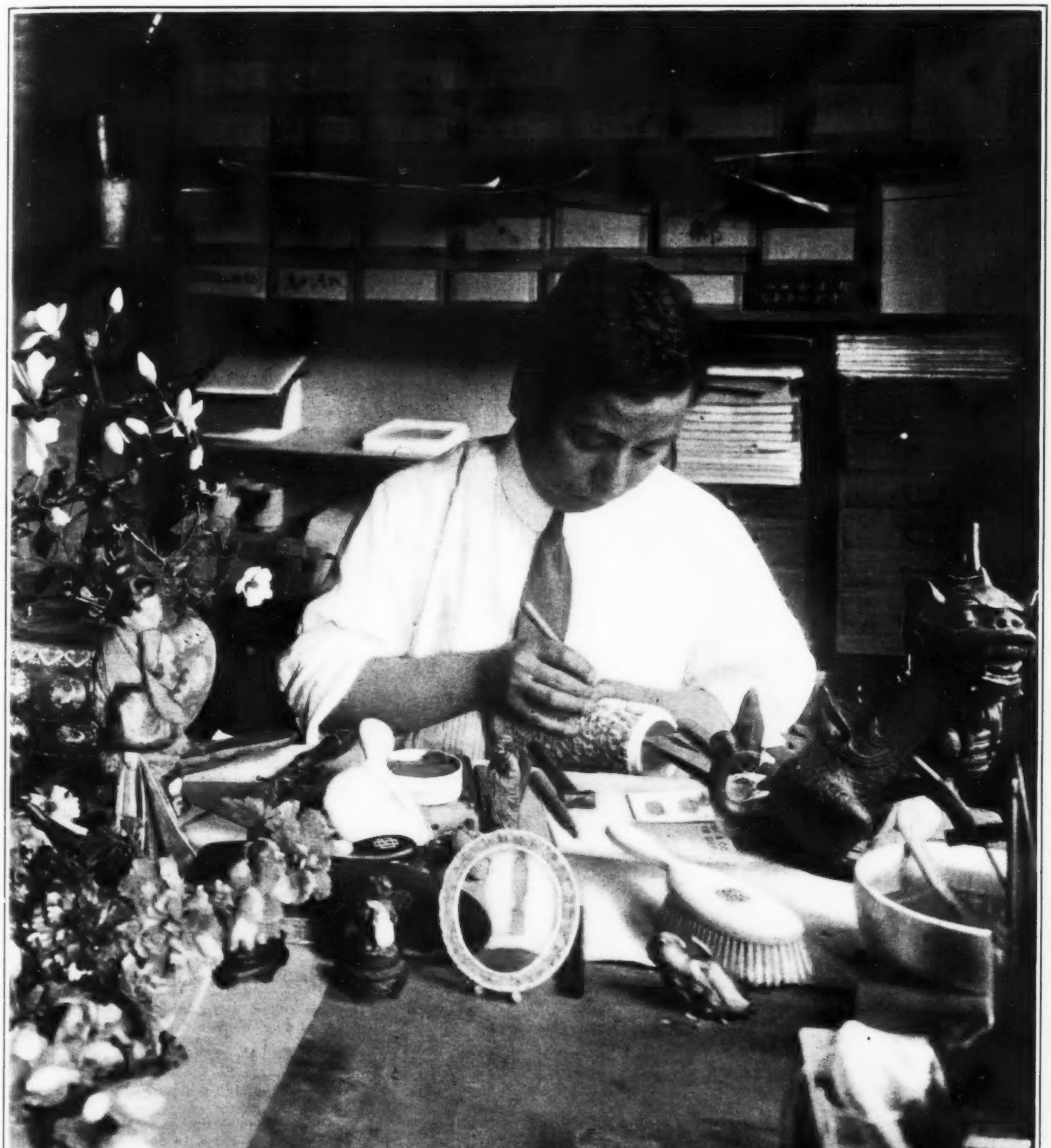


Elaborate ivory work that requires time and patience.

ONE OF THE CURIOUS TRADES OF NEW YORK.—[See page 264.]

New Archæological Lights—I*

On the Origin of Civilization in Europe

By Sir Arthur Evans, D.Litt., LL.D., P.S.A., F.R.S.

The investigations of a brilliant band of prehistoric archæologists, with the aid of representatives of the sister sciences of Geology and Palæontology, have brought together such a mass of striking materials as to place the evolution of human art and appliances in the last Quaternary Period on a far higher level than had even been suspected previously. Following in the footsteps of Lartet, and after him Rivière and Piette, Professors Martailhac, Capitan, and Boule, the Abbé Breuil, Dr. Obermeier, and their fellow-investigators have revolutionized our knowledge of a phase of human culture which goes so far back beyond the limits of any continuous story that it may well be said to belong to an older World.

To the engraved and sculptured works of Man in the "Reindeer Period" we have now to add not only such new specialties as are exemplified by the moulded clay figures of life-size bisons in the Tuc d'Audoubert Cave, or the similar high reliefs of a procession of six horses cut on the overhanging limestone brow of Cap Blanc, but whole galleries of painted designs on the walls of caverns and rock shelters.

So astonishing was this last discovery, made first by the Spanish investigator, Señor de Sautuola—or, rather, his little daughter—as long ago as 1878, that it was not till after it had been corroborated by repeated finds on the French side of the Pyrenees—not, indeed, till the beginning of the present century—that the Palæolithic Age of these rock paintings was generally recognized. In their most developed stage, as illustrated by the bulk of the figures in the Cave of Altamira itself, and in those of Marsoulas in the Haute Garonne, and of Font de Gaume in the Dordogne, these primeval frescoes display not only a consummate mastery of natural design, but an extraordinary technical resources. Apart from the charcoal used in certain outlines, the chief coloring matter was red and yellow ochre, mortars and palettes for the preparation of which have come to light. In single animals the tints are varied from black to dark and ruddy brown or brilliant orange, and so, by fine gradations, to paler nuances, obtained by scraping and washing. Outlines and details are brought out by white incised lines, and the artists availed themselves with great skill of the reliefs afforded by convexities of the rock surface. But the greatest marvel of all is that such polychrome masterpieces as the bisons, standing and couchant, or with limbs huddled together, of the Altamira Cave were executed on the ceilings of inner vaults and galleries where the light of day has never penetrated. Nowhere is there any trace of smoke, and it is clear that great progress in the art of artificial illumination had already been made. We now know that stone lamps, decorated with the engraved head of an ibex, existed.

Such was the level of artistic attainment in Southwestern Europe, at a modest estimate some 10,000 years earlier than the most ancient monuments of Egypt or Chaldæa! Nor is this an isolated phenomenon. One by one, characteristics, both spiritual and material, that had been formerly thought to be the special marks of later ages of mankind have been shown to go back to that earlier world. I myself can never forget the impression produced on me as a privileged spectator of a freshly uncovered interment in one the Balzi Rossi Caves—an impression subsequently confirmed by other experiences of similar discoveries in these caves, which together first supplied the concordant testimony of an elaborate cult of the dead on the part of Aurignacian Man. Tall skeletons of the highly developed Cro-Magnon type lay beside or above their hearths, and protected by great stones from roving beasts. Flint knives and bone javelins had been placed within reach of their hands, chaplets and necklaces of sea-shells, fish-vertebræ, and studs of carved bone had decked their persons. With these had been set lumps of iron peroxide, the red stains of which appeared on skulls and bones, so that they might make a fitting show in the Under-world.

"Colors, too, to paint his body,
Place within his hand,
That he glisten, bright and ruddy,
In the Spirit-Land!"[1]

*From the presidential address before the annual meeting of the British Association, 1916.

[1]Schiller, "Nadowessier's Todtenlied."

Nor is it only in this cult of the departed that we trace the dawn of religious practices in that older World. At Cogul we may now survey the ritual dance of nine skirted women round a male Satyre-like figure of short stature, while at Alpera a gowned sister ministrant holds up what has all the appearance of being a small idol. It can hardly be doubted that the small female images of ivory, steatite, and crystalline talc from the same Aurignacian stratum as that of the Balzi Rossi interments, in which great prominence is given to the organs of maternity, had some fetishistic intention. So, too, many of the figures of animals engraved and painted on the inmost vaults of the caves may well have been due, as M. Salomon Reinach has suggested, to the magical ideas prompted by the desire to obtain a hold on the quarries of the chase that supplied the means of livelihood.

In a similar religious connection may be taken the growth of a whole family of signs, in some cases obviously derivatives of fuller pictorial originals, but not infrequently simplified to such a degree that they resemble or actually reproduce letters of the alphabet. Often they occur in groups like regular inscriptions, and it is not surprising that in some quarters they should have been regarded as evidence that the art of writing had already been evolved by the men of the Reindeer Age. A symbolic value certainly is to be attributed to these signs, and it must at least be admitted that by the close of the late Quarternary Age considerable advance had been made in hieroglyphic expression.

The evidence of more or less continuous civilized development reaching its apogee about the close of the Magdalenian Period have been constantly emerging from recent discoveries. The recurring "tectiform" sign had already clearly pointed to the existence of huts or wigwams; the "scutiform" and other types record appliances yet to be elucidated, and another sign well illustrated on a bone pendant from the Cave of St. Marcel has an unmistakable resemblance to a sledge.[2] But the most astonishing revelation of the cultural level already reached by primeval man has been supplied by the more recently discovered rock paintings of Spain. The area of discovery has now been extended there from the Province of Santander, where Altimira itself is situated, to the Valley of the Ebro, the Central Sierres, and to the extreme Southeastern region, including the Provinces of Albacete, Murcia, and Almeria, and even to within the borders of Granada.

One after another, features that had been reckoned as the exclusive property of Neolithic or later Ages are thus seen to have been shared by Palæolithic Man in the final stage of his evolution. For the first time, moreover, we find the productions of his art rich in human subjects. At Cogul the sacral dance is performed by women clad from the waist downwards in well-cut gowns, while in a rock-shelter of Alpera,[3] where we meet with the same skirted ladies, their dress is supplemented by flying sashes. On the rock painting of the Cueva de la Vieja, near the same place, women are seen with still longer gowns rising to their bosoms. We are already a long way from Eve!

It is this great Alpera fresco which, among all those discovered, has afforded most new elements. Here are depicted whole scenes of the chase in which bow-men—up to the time of these last discoveries unknown among Palæolithic representations—take a leading part, though they had not as yet the use of quivers. Some are dancing in the attitude of the Australian Correborees. Several wear plumed headdresses, and the attitudes at times are extraordinarily animated. What is specially remarkable is that some of the groups of these Spanish rock paintings show dogs or jackals accompanying the hunters, so that the process of domesticating animals had already begun. Hafted axes are depicted as well as cunningly shaped throwing sticks. In one case at least we see two opposed bands of archers—marking at any rate a stage in social development in which organized warfare was possible—the beginnings, it is to be feared, of "kultur" as well as of culture!

[2]This interpretation, suggested by me after inspecting the object in 1902, has been approved by the Abbé Breuil (*Anthropologie*, XIII. p. 152) and by Prof. Sollas, "Ancient Hunters," 1915, p. 480.

[3]That of Carasoles del Bosque; Breuil, *Anthropologie*, XXVI. 1915, p. 329 *seqq.*

Nor can there be any question as to the age of these scenes and figures, by themselves so suggestive of a much later phase of human history. They are inseparable from other elements of the same group, the animal and symbolic representations of which are shared by the contemporary school of rock-painting north of the Pyrenees. Some are overlaid by palimpsests, themselves of Palæolithic character. Among the animals actually depicted, moreover, the elk and bison distinctly belong to the Late Quaternary fauna of both regions, and are unknown there to the Neolithic deposits.

THE REINDEER AGE.

In its broader aspects this field of human culture, to which, on the European side, the name of Reindeer Age may still on the whole be applied, is now seen to have been very widespread. In Europe itself it permeates a large area—defined by the boundaries of glaciation—from Poland, and even a large Russian tract, to Bohemia, the upper course of the Danube and of the Rhine, to Southwestern Britain and Southeastern Spain. Beyond the Mediterranean, moreover, it fits on under varying conditions to a parallel form of culture, the remains of which are by no means confined to the Cis-Saharan zone, where incised figures occur of animals like the long-horned buffalo (*Bubalus antiquus*) and others long extinct in that region. This Southern branch may eventually be found to have a large extension. The nearest parallels to the finer class of rock-carvings as seen in the Dordogne are, in fact, to be found among the more ancient specimens of similar work in South Africa, while the rock-paintings of Spain find their best analogies among the Bushmen.

Glancing at this Late Quaternary culture as a whole, in view of the materials supplied on the European side, it will not be superfluous for me to call attention to two important points which some observers have shown a tendency to pass over.

Its successive phases, the Aurignacian, the Solutrean, and the Magdalenian, with its decadent Azilian offshoot—the order of which may now be regarded as stratigraphically established—represent on the whole a continuous story.

I will not here discuss the question as to how far the disappearance of Neanderthal Man and the close of the Moustierian epoch represents a "fault" or gap. But the view that there was any real break in the course of the cultural history of the Reindeer Age itself does not seem to have sufficient warrant.

It is true that new elements came in from more than one direction. On the old Aurignacian area, which had a trans-Mediterranean extension from Syria to Morocco, there intruded on the European side —apparently from the East—the Solutrean type of culture, with its perfected flint-working and exquisite laurel-leaf points. Magdalenian Man, on the other hand, great as the proficiency that he attained in the carving of horn and bone, was much behind in his flint-knapping. That there were dislocations and temporary setbacks is evident. But on every side we still note transitions and reminiscences. When, moreover, we turn to the most striking features of this whole cultured phase, the primeval arts of sculpture, engraving, and painting, we see a gradual upgrowth and unbroken tradition. From mere outline figures and simple two-legged profiles of animals we are led on step by step to the full freedom of the Magdalenian artists. From isolated or disconnected subjects we watch the advance to large compositions, such as the hunting scenes of the Spanish rock-paintings. In the culminating phase of this art we even find impressionist works. A brilliant illustration of such is seen in the galloping herds of horses, lightly sketched by the engraver on the stone slab from the Chaumont Grotto, depicting the leader in each case in front of his troop, and its serried line—straight as that of a well-drilled battalion—in perspective rendering. The whole must be taken to be a faithful memory sketch of an exciting episode of prairie life.

The other characteristic feature of the culture of the Reindeer Age that seems to deserve special emphasis, and is almost the corollary of the foregoing

is that it cannot be regarded as the property of a single race. It is true that the finely-built Cro-Magnon race seems to have predominated, and must be regarded as an element of continuity throughout, but the evidence of the co-existence of other human types is clear. Of the physical characteristics of these it is not my province to speak. Here it will be sufficient to point out that their interments, as well as their general associations, conclusively show that they shared, even in its details, the common culture of the Age, followed the same fashions, plied the same arts, and were imbued with the same beliefs, as the Cro-Magnon folk. The negroid skeletons intercalated in the interesting succession of hearths and interments of the Grotte des Enfants at Grimaldi had been buried with the same rites, decked with the same shell ornaments, and were supplied with the same red coloring-matter for use in the Spirit World, as we find in the other sepultures of these caves belonging to the Cro-Magnon race. Similar burial rites were associated in this country with the "Red Lady of Paviland," the contemporary Aurignacian date of which is now well established. A like identity of funeral custom recurred again in the sepulture of a man of the "Brünn" race on the eastern boundary of this field of culture.

In other words, the conditions prevailing were analogous to those of modern Europe. Cultural features of the same general character had imposed themselves on a heterogeneous population. That there was a considerable amount of circulation, indeed—if not of primitive commerce—among the peoples of the Reindeer Age is shown by the diffusion of shell or fossil ornaments derived from the Atlantic, the Mediterranean, or from inland geological strata. Art itself is less the property of one or another race than has sometimes been imagined indeed, if we compare those products of the modern carver's art that have most analogy with the horn and bone carvings of the cave men and rise at times to great excellence—as we see them, for instance, in Switzerland or Norway—they are often the work of races of very different physical types. The negroid contributions, at least in the Southern zone of this late Quaternary field, must not be underestimated. The early steatopygous images—such as some of these of the Balzi Rossi caves—may safely be regarded as due to this ethnic type, which is also represented in some of the Spanish rock-paintings.

The nascent flame of primeval culture was thus already kindled in that older world, and, so far as our present knowledge goes, it was in the southwestern part of our continent, on either side of the Pyrenees, that it shone its brightest. After the great strides in human progress already made at that remote epoch, it is hard, indeed, to understand what it was that still delayed the rise of European civilization in its higher shape. Yet it had to wait for its fulfilment through many millennia. The gathering shadows thickened and the darkness of a long night fell not on that favored region alone, but throughout the wide area where reindeer man had ranged. Still the question rises—as yet imperfectly answered—were there on relay runners to pass on elsewhere the lighted torch?

Something, indeed, has been recently done towards bridging over the "hiatus" that formerly separated the Neolithic from that Palæolithic Age—the yawning gulf between two worlds of human existence. The Azilian—a later decadent outgrowth of the preceding culture—which is now seen partially to fill the lacuna, seems to be in some respects an impoverished survival of the Aurignacian.[4] The existence of this phase was first established by the long and patient investigations of Piette in the stratified deposits of the Cave of Mas d'Azil in the Ariège, from which it derives its name, and it has been proved by recent discoveries to have had a wide extension. It affords evidence of a milder and moister climate—well illustrated by the abundance of the little wood snail (Helix nemoralis) and the increasing tendency of the reindeer to die out in the southern parts of the area, so that in the fabric of the characteristic harpoons, deer-horns are used as substitutes. Artistic designs now fail us, but the polychrome technique of the preceding age still survives in certain schematic and geometric figures, and in curious colored signs on pebbles. These last first came to light in the Cave of Mas d'Azil, but they have now been found to recur much further afield in a similar association in grottoes from the neighborhood of Basel to that of Salamanca. So like letters are some of these signs that the lively imagination of Piette saw in them the actual characters of a primeval alphabet!

The little flakes with a worked edge often known as "pygmy flints," which were most of them designed for insertion into bone or horn harpoons, like some Neolithic examples, are very characteristic of this stratum, which is widely diffused in France and elsewhere under the misleading name of "Tardenoisian." At Offnet, in Bavaria, it is associated with a ceremonial skull burial showing the co-existence at that spot of brachycephalic and dolichocephalic types, both of a new character. In Britain, as we know, this Azilian, or a closely allied phase, is traceable as far north as the Oban caves.

What, however, is of special interest is the existence of a northern parallel to this cultural phase, first ascertained by the Danish investigator, Dr. Sarauw, in the lake station of Maglemose, near the west coast of Zealand. Here bone harpoons of the Azilian type occur, with bone and horn implements showing geometrical and rude animal engravings of a character divergent from the Magdalenian tradition. The settlement took place when what is now the Baltic was still the great "Ancylus Lake," and the waters of the North Sea had not yet burst into it. It belongs to the period of the Danish pine and birch woods, and is shown to be anterior to the earliest shell mounds of the Kitchenmidden People, when the pine and the birch had given place to the oak. Similar deposits extend to Sweden and Norway, and to the Baltic Provinces as far as the Gulf of Finland. The parallel relationship of this culture is clear, and its remains are often accompanied with the characteristic "pygmy" flints. I'reuil, however,[5] while admitting the Late Palæolithic character of this northern branch, would bring it into relation with a vast Siberian and Altaic province, distinguished by the widespread existence of rock-carving of animals. It is interesting to note that a rock-engraving of a reindeer, very well stylized, from the Trondhjem Fjord, which has been referred to the Maglemosian phase, preserves the simple profile rendering—two legs only being visible—of early Aurignacian tradition.

It is worth noting that an art affiliated to that of the petroglyphs of the old Altaic region long survived in the figures of the Lapp trolldrums, and still occasionally lingers, as I have myself had occasion to observe, on the reindeer-horn spoons of the Finnish and Russian Lapps, whose ethnic relationship, moreover, points east of Ural. The existence of a late Palæolithic Province on the Russian side is in any case now well recognized and itself supports the idea of a later shifting north and northeast, just as at a former period it had oscillated in a southwestern direction. All this must be regarded as corroborating the view long ago expressed by Boyd Dawkins[6] that some part of the old cave race may still be represented by the modern Eskimos. Testut's comparison of the short-statured Magdalenian skeleton from the rock shelter of Chancelade in the Dordogne with that of an Eskimo certainly confirms this conclusion.

On the other hand, the evidence, already referred to, of an extension of the Late Palæolithic culture to a North African zone, including rock-sculptures depicting a series of animals extinct there in the later Age, may be taken to favor the idea of a partial continuation on that side. Some of the early rock-sculptures in the south of the continent, such as the figure of a walking elephant reproduced by Dr. Peringuey, afford the clearest existing parallels to the best Magdalenian examples. There is much, indeed, to be said for the view, of which Sollas is an exponent that the Bushmen, who at a more recent date entered that region from the north and whose rock-painting attained such a high level of naturalist art, may themselves be taken as later representatives of the same tradition. In their human figures the resemblances descend even to conventional details, such as we meet with at Cogul and Alpera. Once more, we must never lose sight of the fact that from the Early Aurignacian Period onwards a negroid element in the broadest sense of the word shared in this artistic culture as seen on both sides of the Pyrenees.

At least we now know that Cave Man did not suffer any sudden extinction, though on the European side, partly, perhaps, owing to the new climatic conditions, this culture underwent a marked degeneration. It may well be that, as the osteological evidence seems to imply, some outgrowth of the old Cro-Magnon type actually perpetuated itself in the Dordogne. We have certainly lengthened our knowledge of the Palæolithic. But in the present state of the evidence it seems better to subscribe to Cartailhac's view that its junction with the Neolithic has not yet been reached. There does not seem to be any real continuity between the culture revealed at Manglemose and that of the immediate superposed Early Neolithic stratum of the shellmounds, which, moreover, as has been already said, evidence a change both in climatic and geological conditions, implying a considerable interval of time.

It is a commonplace of archælogy that the culture of the Neolithic peoples throughout a large part of Central, Northern and Western Europe—like the newly-domesticated species possessed by them—is Eurasiatic in type. So, too, in Southern Greece and the Ægean World we meet with a form of Neolithic culture which must be essentially regarded as prolongation of that of Asia Minor.

It is clear that it is on this Neolithic foundation that our later civilization immediately stands. But in the constant chain of actions and reactions by which the history of mankind is bound together—short of the extinction of all concerned, a hypothesis in this case excluded—it is equally certain that no great human achievement is without its continuous effect. The more we realize the substantial amount of progress of the men of the Late Quaternary Age in arts and crafts and ideas, the more difficult it is to avoid the conclusion that somewhere "at the back of behind"—it may be by more than one route and on more than one continent, in Asia as well as Africa—actual links of connection may eventually come to light.

ORIGINS OF EUROPEAN CULTURE.

Of the origins of our complex European culture this much at least can be confidently stated: the earliest extraneous sources on which it drew lay respectively in two directions—in the Valley of the Nile on one side and in that of the Euphrates on the other.

Of the high early culture in the lower Euphrates Valley our first real knowledge has been due to the excavations of De Sarzec in the Mounds of Tello, the ancient Lagash. It is now seen that the civilization that we call Babylonian, and which was hitherto known under its Semitic guise, was really in its main features an inheritance from the earlier Sumerian race—culture in this case once more dominating nationality. Even the laws which Hammurabi traditionally received from the Babylonian Sun God were largely modelled on the reforms enacted a thousand years earlier by his predecessor, Urukagina, and ascribed by him to the inspiration of the City God of Lagash.[7] It is hardly necessary to insist on the later indebtedness of our civilization to this culture in its Semitized shape, as passed on, together with other more purely Semitic elements, to the Mediterranean World through Syria, Canaan, and Phœnicia, or by way of Assyria, and by means of the increasing hold gained on the old Hittite region of Anatolia.

Even beyond the ancient Mesopotamian region which was the focus of these influences, the researches of De Morgan, Gautier, and Lampre, of the French "Délégation en Perse," have opened up another independent field, revealing a nascent civilization equally ancient, of which Elam—the later Susiana—was the centre. Still further afield, moreover—some three hundred miles east of the Caspian—the interesting investigations of the Pumpelly Expedition in the mounds of Anau, near Ashkabad in Southern Turkestan, have brought to light a parallel and related culture. The painted Neolithic sherds of Anau, with their geometrical decoration, similar to contemporary ware of Elam, have suggested wide comparisons with the painted pottery of somewhat later date found in Cappadocia and other parts of Anatolia, as well as the North Syrian regions. It has, moreover, been reasonably asked whether another class of painted Neolithic fabrics, the traces of which extend across the Steppes of Southern Russia, and, by way of that ancient zone of migration, to the lower Danube and Northern Greece, may not stand in some original relation to the same ancient province. The new discoveries, however, in the mounds of Elam and Anau, have had at most a bearing on the primitive phase of culture in parts of Southeastern Europe that preceded the age when metal was generally in use.

(To be concluded.)

[4]Breuil, "Congr. Préhist." Geneva, 1912, p. 216.

[5]"Les subdivisions du paléolithique supérieur et leur signification."—"Congrès. intern. d'Anthrop, et d'Archéol. préhist., XIVme Sess., Genève," 1912, pp. 165, 238.

[6]"Early Men in Britain," 1880, p. 233 *seqq.*

[7]See L. W. King, "History of Summer and Akkad," p. 184.

How Shells Can Kill Without Wounding.

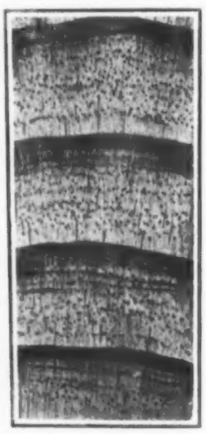
In a note which Dr. J. Lepine presented to the Académie de Médecine, he explains the fact that the explosion of heavy shells can kill persons without apparent wounds. This effect is due to a perturbation of the nervous centres, arising from the explosion of the heavy shells, and the consecutive actions which are produced. Such perturbations are caused by a sudden distention of the circulatory system of the human body due to a sudden pressure exercised upon the whole surface of the body. This pressure reaches a maximum upon the abdominal region, from which all the visceral blood is driven toward the interior portion of a body.

Determining the Age of Blazes

A Useful Lesson in Woodcraft

A BLAZE or mark is a cut on a tree trunk made by removing a portion of the bark and a thin layer of the wood by means of an ax or hatchet. In common parlance the terms "blaze" and "mark" are used interchangeably, but surveyors usually recognize the following distinctions: A blaze is an ax-scar on a tree trunk along a survey line by means of which a line may be located or retraced between corners. Such scars are commonly from four to six inches long and from two to three inches wide. A mark on a tree trunk consists of several hacks one above the other or in the form of a cross or the letter *X*. A scar of this character indicates a point, corner or intersection of lines.

It is very important that all blazes and marks remain recognizable on the trunks until the trees are cut down



Loblolly pine showing very wide annual rings of growth.

or are otherwise destroyed. This result can be attained only by cutting completely through the bark into the wood. The part of the wood exposed to the air loses its vitality, dies and turns black. The cambium, which is the microscopic layer of actively dividing cells developing wood on the inside and bark on the outside, is thus removed and growth at this particular point on the trunk ceases until the exposed area is entirely healed over and a continuous cambium again developed.

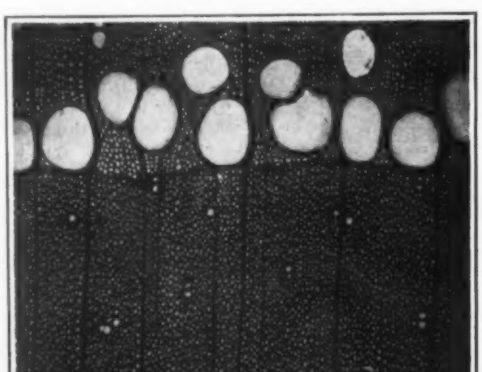
In the case of massive trees like the sequoias and Douglas fir which develop bark occasionally a foot thick, it is usually difficult to cut completely through the bark and remove a thin layer of the wood. In actual practice the bark of such trees is seldom cut through. In small and fast growing trees the scars invariably heal over in course of time, leaving what is known as blind scars. These blind scars are difficult of recognition even by the trained woodsmen, especially in trees like the aspens and birches, which have a thin, smooth and nearly white bark when young, but which develop a thick, deeply-divided ridged bark later in life. If such trees are blazed when young the scars become completely obliterated through the development of the thick corky outer layer. Mature trees usually grow very slowly in diameter and deep hacks into the outer bark often remain recognizable for many years, but the age of such scars cannot be determined, for the reason that there are no annual rings of growth shown in the transverse section of the bark.

The age of blaze marks, in the absence of other records, can easily be determined by the number of annual rings of growth laid on since the wound was made. All trees in the temperate climate deposit annually a distinct layer of wood immediately beneath the bark. This woody tissue is generated by a thin layer of actively dividing cells (cambium) lying between the wood and the bark. These living cells divide longitudinally, that is, in the direction of the axis of the stem, and new wood elements are laid on, thus increasing the diameter of the stem and the branches. The cells given off toward the inside develop into thick-walled woody fibers, which are grouped into distinct layers of growth or annual rings, while those given off toward the outside produce chiefly thin-walled elements or bark, which shows no such distinct layers.

As long as the cambium remains intact and the cells continue to divide, the tree trunk increases in diameter. During the time of the year when climatic conditions are unfavorable to growth the cambium cells remain inactive and the tree is said to be at rest. In the spring of the year as soon as there is sufficient warmth and moisture in the soil the cells resume activity, which results in more or less rapid diameter increase at the beginning of the growing season, but which gradually

A fresh blaze on a lodgepole pine tree.

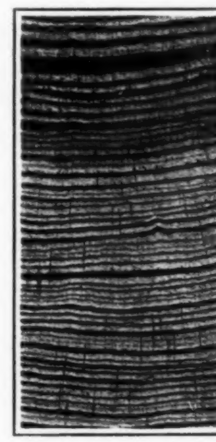
becomes slower toward the end of summer. The cells formed during the spring months are large and thin-walled, while those laid on during the latter half of the season are small, thick-walled and are usually flattened radially, thus rendering the outer portion of the ring



Cross section of black ash, showing the character of ring-porous woods.

denser and more conspicuous than the inner and more porous part. The stem of the oak or yellow pine, for instance, exhibits in a transverse section more or less clearly defined rings. Under normal conditions one of these rings is formed each year, and for this reason it is called annual ring of growth. Fast-growing trees have very wide rings distinctly marked, while slow-growing ones have very narrow rings scarcely visible to the unaided eye.

There are two main groups of woods, namely: Non-porous or softwoods and porous or hardwoods. The first group includes woods without pores. Pines, spruces and firs have no pores and belong to this group. The second group includes woods with large pores arranged chiefly in the inner part of the ring and are known as ring porous woods. The oak, chestnut and sassafras are good examples of this group. There is also included in this group a class of woods having the large and small pores distributed evenly throughout the annual rings of growth; these are known as diffuse-porous



Loblolly pine showing comparatively narrow annual rings of growth.

woods and are represented by such woods as the birch, willow and poplars.

For the determination of the age of blazes the annual rings of growth are relied upon, and it is important, therefore, to know the manner in which the wounds in trees heal. In this connection Forest Service Circular, No. 16, is quoted as follows: "On each side of the blaze the cambium is killed for but a very short distance, and growth not only continues in the uninjured part, but is commonly even stimulated by the process of wounding, so that the cambial growth, together with the growth of the uninjured part of the live bark, soon forms a rampart-like thickening, the 'callus,' around the blaze. The callus is the thickest on the two sides, least so on the lower point; and thickens and encroaches more and more on the wood surface. In time this growth covers the entire blaze, the callus from one side meeting that from the other. Usually the bark is pressed out so that a perfect union forms between these two, and in almost all cases the wood grows firmly along the dead wood of the blaze, filling out all its depressions and producing an exact matrix of the old blaze, so that any inscriptions are faithfully recorded in this cover as well as in the old wood. After the cover is complete the blaze ceases, of course, to be visible, and its position is merely indicated by a depression corresponding to the thinner and smoother bark on the old blaze and the thickened remains of the old rampart-like callus."

In order to count accurately the rings of growth laid on since the blaze was made, it will be necessary to make a cross section of the stem or part of the stem passing through the middle of the blaze. It is desirable next to make a clean, smooth cut by means of a sharp knife from the edge of the old blaze radially to the bark. The number of rings or layers laid on between the bark and the edge of the wound represents the age of the blaze. Generally a pocket lens magnifying five or ten diameters will be very helpful in counting the rings which are sometimes very difficult to see with the unaided eye.

Old Time Standard in Europe

PREVIOUS to 1891 there were twenty-four different standards of time of European railways, now reduced to three, and the times of the following capitals: Paris, Lisbon, Rome, Berne, Athens, Copenhagen, Christiania, Petrograd and Dublin.

A Fossil Nutmeg From the Tertiary of Texas*

By Edward Wilbur Berry

The Nutmegs, with somewhat less than 100 existing and widely distributed tropical forms, constitute the family Myristicaceæ of the order Ranales. Satisfactorily determined fossil forms are entirely unknown so that the remains which form the subject of the present paper are not without interest.

These are found in the Catahoula formation of Trinity County in eastern Texas from which I described the fruits of a date palm some years ago,[1] and were collected by Charles Laurence Baker. The matrix of this material was the basis for a highly interesting study of the petrography of the Catahoula sandstone made by M. I. Goldman[2] and published in this Journal in 1915. The evidence of the flora and that furnished by the study of the sediments supplement one another in throwing considerable light on the physical conditions of Catahoula time which will be referred to on a subsequent page.

The fossil species of nutmeg, obviously new, is represented by characteristic remains of the pericarp and of the seeds. It may be described as follows:

MYRISTICA CATAHOULENSIS, SP. NOV.

Pericarp broadly ovate, slightly longer than wide, approximately circular in cross section, thick, two-valved, about 5cm in length and 3.75cm in diameter, enclosing a single large seed. The aril either decayed before fossilization or became separated from the seed and was not preserved in the same deposit and the perisperm is likewise missing. The seed is large, circular in cross section, evenly rounded proximad and shows a distinct hilum. It is slightly narrowed and bluntly pointed distad. The surface is ornamented by numerous irregular longitudinal corrugations marking the ruminating endosperm. These markings are in faint relief and much less prominent than the corresponding markings of the commercial nutmeg, due in a measure to the fact that fossils are all casts in a somewhat porous sandstone. Similar artificial casts of the strongly marked commercial nuts are scarcely to be distinguished from the fossil casts. The nuts, of which several have been found, are about 3cm in length by 1.7cm in maximum diameter, which is midway between the apex and the base.

This species is based on the single valve of the pericarp and on the partial remains of several of the nuts discovered, only one of which is perfect. The nuts were apparently relatively abundant, but since they were only discovered in the weathered sandstone there are few that are reasonably complete although there are several showing parts of the sides or ends, in some cases half complete.

As I have mentioned, all the plant remains at this locality are in the form of casts and the nuts must have been buried by wind-blown sand since they lie in the sand at all angles. The æolian character of the sandstone at this outcrop is of the greatest importance in explaining the absence of both aril and perisperm, and is, therefore, deserving of comment. The evidence for this conclusion is derived from several sources. Many of the leaf specimens are curled and not flat as they would almost invariably be if laid down in water. These and other associated nuts are jumbled in a confused mass at all angles. Violent currents could form such a jumble, but the nuts would not be heavy enough to be deposited under such conditions but would be carried away by water action strong enough to stand them on end, nor would waterlogging in more quiet waters explain their varying positions. Associated with nutmegs are much more numerous large-ribbed nuts as yet unidentified. These lie at all angles in the sandstone but occur elsewhere in clays, in which case they invariably lie on their sides. The conclusions of Dr. Goldman, based on a petrographic study of the matrix, *i.e.*, the proportion of different sizes of grains present, their rounding, the ratio of feldspar to quartz, the degree of weathering, absence of clay, proportion of heavy minerals, etc., for a detailed discussion of which the reader is referred to the paper cited, point to strong æolian action in a hot arid climate.

The nuts are fully matured and evidently were shed naturally and at no great distance from the sand flats where they subsequently became entombed. The sediments do not, according to Dr. Goldman, show characters of dune sands, and I infer that the winds which rounded and sorted the sand grains were not constant enough in direction to form dunes of any size. Under such conditions of blowing about the arils would soon be lost, but the perisperm cannot be conceived of as being so readily dissipated although I know of no other method to account for its absence. It must be remembered that less than a dozen nuts are known, that much of the sand from near-by outcrops appears to have been blown into pools of standing water where the accompanying leaves were fossilized in a normal flat condition, and that the small percentage of nutmegs preserved in the wind-blown sands may thus be exceptional when the possibility is considered of large numbers fossilized in a normal way with perisperm intact.

That the fossils are unmistakably those of a species of Myristica I think no botanist will dispute. No leaves that I can identify as those of Myristica have as yet been determined, but the leaf material is scanty, and I have not enough recent material of this genus for intelligent comparison of the foliar organs.

The recent species of this family which number about 90 forms are variously treated. De Candolle[3] referred them all to the single genus Myristica which he segregated into 13 sections, and this is the method followed by Prantl[4] in *Die Natürlichen Pflanzenfamilien*. Other authors raise a number of these sections to generic rank, quite rightly so it seems to me. I have, however, preferred to refer the fossil to Myristica since comparative recent material for closer discrimination is lacking. The nutmeg of commerce belongs to the section Eumyristica with about 15 existing species of the Asiatic tropics. It is a small tree, endemic in the Moluccas and has long been under cultivation judging both from the numerous varieties extant and the historical records, since Europe has been receiving nutmegs from this region, beginning with the trade through the Arabs in the 6th century. The nutmeg has been introduced into other East Indian islands as well as on Bourbon, Mauritius, Madagascar and in tropical America, usually with indifferent success.

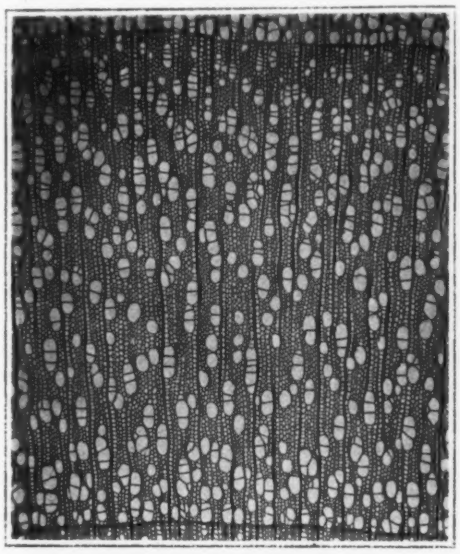
While the Texas fossil is much like the commercial nutmeg in size and characters it is also similar to existing American species, of which there are about twenty-five. These are mainly South American, but the sections or genera *Virola* Aublet and *Compsoneura* De Candolle both occur also in Central America. The fossil nuts are remarkably like those of *Myristica* (*Compsoneura*) *costaricensis* Warburg, but the pericarp is much larger and more massive.

Beyond the fact that they are tropical I know little regarding the habitat of the recent species. Many are certainly insular and coastal forms, their range in the Pacific extending eastward to the Fiji, Tonga and Samoan islands, the former having 4 or 5 species. Schimper records 4 species in his Indomalayan strand flora. *Myristica subcordata* Blume of New Guinea and *Myristica littoralis* Miquel of Java are both members of Barringtonia or beach-jungle association. Both Gaudichand and Guppy record unopened Myristica fruits in the Pacific sea-drift although their floating powers are not great and they are normally dispersed by fruit pigeons (Moseley, Hemsley, Guppy).

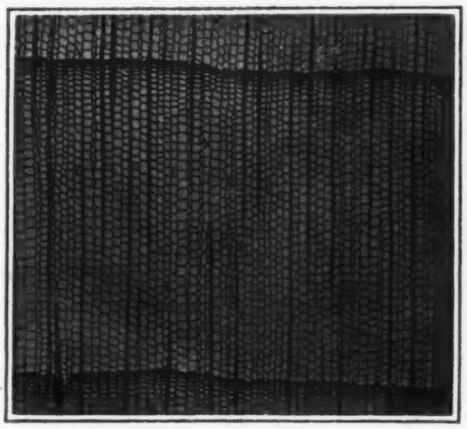
Referring to the foliage it may be noted that contrary to the opinion of Hooker and Thomson (Flora Indica), De Candolle found that the flowers and fruits were much alike throughout the family and that the leaves furnish the most useful characters for differentiation, especially in their venation, and this opinion was also shared by Miquel. It would seem that the lack of comparative material has hitherto prevented the recognition of fossil foliage of Myristica. Certainly no definite evidence of extinct species has heretofore been published although the distribution of the existing species in tropical Asia, Africa and America is convincing enough evidence that the group had an extensive, even if unknown, Tertiary history. The only previously known fossil records are based on a very few and indifferently characterized leaf impressions from the Miocene of Labuan (Borneo) described by Geyler[5] as *Myristicophyllum majus* and *minus*, and by equally unconvincing leaf fragments described by Engelhardt as *Myristica fossilis*[6] and coming from beds in Equador and Chile considered to be either Eocene or Oligocene in age.

On the other hand, the family Anonaceæ, which is closely related to the Myristicaceæ, is represented in the fossil record by over a score of species of Anona, Asimina, Guatteria, etc., ranging in age from the early Upper Cretaceous through the Teritary. Both Anona and Asimina are represented in the Lower Eocene flora of the Mississippi embayment area.

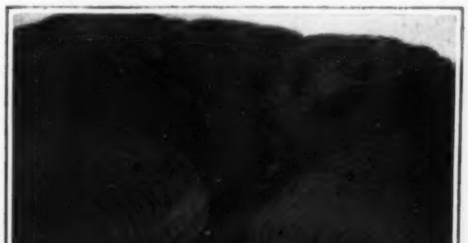
Myristica catahoulensis comes from a cut on the International and Great Northern Railroad in southern Trinity County, where a spur to the Government lock leaves the main line, and the Catahoula formation in this area is either late Eocene of early Oligocene in age. The flora is a coastal one and strictly tropical in character.



Cross section of poplar wood, showing the character of diffuse porous woods.



Cross section of fir, showing the character of non-porous woods.



Transverse section through a blaze on Douglas fir laid on since tree was blazed 30 years ago.

Transverse section through the stem of lodgepole pine, showing the healing over of an amputated branch.

*Am. Journal of Science.
[1]Am. Journal of Science (4), xxxvii, pp. 403-406, 1914.
[2]Ibid., xxxix, pp. 261-287, 1915.
[3]Ann. Sci. Nat., 4th ser., Bot. tome iv, pp. 20-31.
[4]Teil III, Abth. 2, 1891.
[5]Geyler, Vega Exped., vol. iv, p. 498, pl. 33, figs. 3-6, 1887.
[6]Abh. Senck. Naturf. Gesell., xvi, Heft 4, 1891, p. 663, pl. 6, f. 9, pl. 7, fig. 12, 1891. Ibid., xix, p. 13, pl. 1, f. 21, 1895.

The Dynamic Balance of Machines*

Necessity For, and Principles by Which Quiet Operation May Be Attained

By Chas. L. Clarke

A BODY at rest produces no external dynamic effect. If mounted on a shaft and rotated, each elemental or narrow cross-section of the body in a plane perpendicular to the axis of the shaft tends to revolve about a right axis passing through its center of gravity; and if the centers of gravity of all the sections lie in the axis of the shaft, this tendency is initially satisfied and no effort or force is required to exercise it, and each section, and therefore the body as a whole, is in running, or dynamic balance—the vector sum of the forces produced in each section by the rotation is zero, and thus no external effect results; the body runs quietly regardless of the speed.

If, on the contrary, the centers of gravity of some of the cross-sections, and therefore the axis about which they tend to revolve, do not lie in the axis of the shaft (which we will assume to be practically rigid, as is generally the case) these sections, and therefrom the body as a whole, are dynamically out of balance. The vector sum of the forces in all the sections will no longer be zero, but surplus or unbalanced forces will exist, which may produce undesirable external effects, appearing most commonly in the form of annoying or harmful vibrations, depending upon the masses involved, the speed and the environments, and sometimes further resulting in excessive twisting and bending stresses in the shaft, and undue journal friction, heating and wear.

Since it is only necessary that the centers of gravity of the cross-sections lie in the axis of the shaft in order for them to be in dynamic balance, this result can be accomplished with practical accuracy, in the majority of cases of machine design, and thus for the body as a whole, by the method of standing, or static balancing, when the construction permits the separate balancing of a sufficient number of sections, or parts, in this manner before they are finally assembled, and particularly such parts as methods of manufacture compelled by commercial exigencies may render liable to be out of balance in their finished state. For example, it may be advisable to balance the commutator and armature of an electric motor separately in this way. Furthermore, the gear-wheel or pulley on the shaft, constituting a part of the whole revolving body, should also be in balance, as in fact, it is supposed to be, when received from the maker.

Again, the size and operating speed may make it desirable to balance parts of the armature and commutator bodies before they are assembled and the coils and bars are applied—it is easy for the designer to picture a structure that will be in perfect balance, as far as the drawings are concerned, but they do not take into account the effect of variations in density of the metal, especially in castings, the presence of blowholes, deformation by irregular shrinkage, etc., which may make balancing necessary by application of metal pieces at proper places to compensate for the defects mentioned, or the cutting off or boring out of metal for the same purpose.

In static balancing the axis of the piece may be centered on a temporary shaft set horizontally on level straight edges, and weight so added, or taken away that the piece remains stationary in any position in which it is rolled along the edges, which indicates that the center of gravity lies in the axis, and thus that the piece is balanced. Or for greater refinement for higher operating speeds an apparatus may be employed in which the axis of the piece, say, a single steam-turbine disk, is vertically centered over a straight line joining and representing the prolongation of two knife-edges of a horizontal rocking table on which the disk is supported. Balance is indicated, when the rocking table remains horizontal for any position of the disk about its axis.

But there are practical limits to the application of the static method of balancing for running operation, however refined. The body may not be separable into sections along the shaft for individual balancing, and therefore must be balanced as a whole. It may be a single casting with two sets of radial spider-arms wide apart in axial direction for support of other parts, say, the laminated steel core and coils of an armature; and even should the casting happen to be in practical balance for good running, the laminated core and coils, when applied, may destroy the balance.

The body, either the casting or the completed armature, can be statistically balanced as a whole, it is true, or so that the center of gravity of the whole mass lies in the axis of the shaft, by adding or subtracting weight at points suitably located circumferentially, although placed anywhere axially. But suppose a set of spider-arms at one end of the body thus balanced, considered by itself as a section thereof, does not have its center of gravity in the axis of the shaft, it will then be dynamically out of balance, and naturally so will be the whole armature; and the condition will be worse if the other set of spider-arms is also out of balance, and especially if its center of gravity is on the opposite side of the axis. In such a case the method of dynamic balancing is resorted to, when feasible of application.

Without dwelling on details of the apparatus employed, of which there are variations in design, it is sufficient to state in general that the body is rotated at operating speed with the shaft and bearings spring-held so as to permit a slight oscillation produced by the out-of-balance condition. The shaft is chalked or leaded, and by gradually advancing a metal stylus until it delicately touches the shaft at the high point of the oscillation a corresponding mark is made, which indicates the location where the weight should be changed. The weight is altered and the test repeated until balance is obtained for that end, when the stylus mark will encircle the shaft. The other end is then balanced in the same way, which completes the balance of the body as a whole in respect to the journals in which the shaft is held.

This is the best that can be accomplished practically, when the body as a whole has to be dynamically balanced; and it will run quietly, if the construction, and especially the shaft, is stiff enough to stand without undue strain the stresses that may be set up by out-of-balance sections. If the construction is weak, however, a good dynamic balance need not be expected; the strains produced by out-of-balance sections may set up incurable oscillations, which may manifest themselves in extended vibrations, and noises varying from a disagreeable rumble to a clashing roar, not to mention hot and cut bearings, and possible crystallizing of material and breakdown. Naturally, we do not here include the possible clatter and singing of laminations in some types of electric machines, and windage, which likewise may amount to a roar in a large machine, as they do not relate to the subject of balancing.

Then there is the case of small high-speed machines, say, small motors, where the cost factor practically prevents close attention to balance until the armature is completed, and thus dynamic balancing, if any balancing is required, must be resorted to.

Finally, we have rotating machine constructions so large and massive that they do not practically lend themselves to more than an approximate balancing by the static method, and for the dynamic balancing of which it is not commercially practicable to install a special apparatus of the general character heretofore indicated, because it would have to be of comparatively huge dimensions, would be very costly and would not be used enough to warrant the outlay. In this case such balancing as is practicable is accomplished under running conditions by shifting weights by the cut-and-dry method, the effort being to minimize vibrations in the machine, its foundations and surroundings, and bearing friction, until good continuously-running conditions are obtained.

We have heretofore specifically dealt only with rotary bodies, but may include broadly among the machines that have to be balanced, when necessary, by cut-and-dry method those having connected rotating and oscillating and reciprocating members, for example, the crank, pitman, piston-rod and piston of a reciprocating steam engine. Here balancing is a complicated compromise between purposely produced surplus dynamic effects of out-of-balance rotation of one body and the dynamic effects of other connected non-rotating, but moving bodies, taken in connection with suitably adjusted energy transference from the bodies to the steam by compression of the latter. The balance at best is a rough one compared with that obtainable for a rotary body alone; in practice it is attained by careful attention to original design, as far as possible, and improved, if found essential, by redistribution of weight in one or more of the moving parts of the completed machine, or change in the steam compression by proper valve adjustment, or both.

Time was, when rotative speeds, taken in connection with the masses involved, represented dynamic effects much less in amount than we find common to-day. The ever-growing urgency that machines shall attain the highest practicable efficiency calls for speeding-up rotating elements—in electrical machines, for instance, the copper and accompanying iron must travel as fast as possible, in this almost over-fast era, and sometimes the materials are, in fact, made to travel too fast, and out-of-balance manifests itself, which would not have been the case had not the chase for exceeding efficiency resulted in the exaggeration of dynamic effects not before of noticeable or serious amount; hence the necessity for still better balancing.

And on top of the refinement in balancing necessary for engineering reasons, comes a growing insistence on a condition of reasonable quietude in relation to the operation of machines in many of their applications, which may be expressed as proceeding from a condition of nerves—people are getting more "touchy"; their perceptive faculties for noise and vibrations are more acute and more easily upset than formerly; there is jolt and jar and clangor enough without adding to it, when avoidable, and with the rapidly increasing use of machines, as the electric motor, in the home and business places, no noise or vibration of distracting amount should enter with them; and in the factory, where line shafting and belts have been supplanted by motors, the continuous purr of the former must not be replaced by an annoying high-pitch tremble or deep rumble coming from ill-balanced motors—not forgetting screechy commutator brushes, albeit outside the present topic. And it may not be amiss to add, as a reminder, that the quiet machine, other things being equal, will get the market.

Naturally, a physically perfect balance is not attainable; therefore a good-enough balance is the result to be sought, which leads us to the point that a balance good enough for a certain environment may be a bad out-of-balance in other surroundings—a machine that runs quietly on a floor, or even less massive support, as far as our senses are affected thereby, may kick up unendurable antics by way of vibrations and noises, if placed on some frail support, say, a shelf fixed to a thin partition; and a large high-power machine that seems as docile as a kitten when on a massive monolith of concrete, may act like a roaring lion, if set up on a steel structure, built however strong within reason, threatening destruction to everything around.

It goes without saying that a machine should be so designed and built as to be efficient and durable within practicable limits, and so that it cannot be harmed merely by its own operation. When this object is attained the refinement to which the balance should be carried depends upon conditions under which the machine is installed and used. Generally, in the case of a high-power machine of individual design, to meet specific requirements, the refinement of balance is limited to that necessary for durability and economy of operation, and the making of a proper foundation is relied upon to minimize extraneous vibrations and noise through such out-of-balance conditions as remain.

But commercial requirements also call for the designing of standard types of machines, made in quantities to meet quick demands of a general market. In this case the refinement of balance depends upon the average place and condition of use, as far as can reasonably be prejudged. Nevertheless, should one of these machines happen to be installed under adverse conditions, especially conditions that resonate with such out-of-balance as the machine may have, it is promptly blamed for the trouble and quite likely condemned; whereas often it might easily be made to run all right by exercising a little common-sense in slightly modifying the surroundings.

For example, a machine set directly on a floor may cause disagreeable vibrations, which might be overcome by setting it up on a boxing filled with concrete. The very annoying hammer of a high-speed reciprocating engine set on a ledge of rock, which was transmitted in the dead of night to homes throughout the neighborhood, was permanently suppressed by interposing a medium of India rubber between the engine bed and ledge, and under the heads of the anchor-bolts. In an-

*The General Electric Review.

other case six high-speed engines, balanced as perfectly as the design practically permitted, and installed on a flooring supported by heavy iron beams, oscillated the beams to a dangerous extent; the resonating cause of the trouble was removed by placing along under the center of the floor beams a lighter beam supported on columns of ordinary heavy iron pipe set on the concrete basement floor; the light beam bore only an insignificant part of the weight, but stopped the oscillation. Analagous examples might be mentioned almost without limit, representing the exercise of good judgment in nullifying at comparatively small expense the undesirable effects that machines have tended to produce under adverse surroundings.

In conclusion: when a machine is apparently badly out of balance, do not be in haste to condemn it. Look into the conditions of its use and see whether they may not reasonably be so modified as to cause the apparently undue out-of-balance to disappear—else it may prove to be largely oneself, from the all-around technical and also commercial point of view, that is in reality out-of-balance.

Correspondence

[The editors are not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.]

Bronze in Catskill Aqueduct

To the Editor of the SCIENTIFIC AMERICAN SUPPLEMENT:

AN article by Clements E. Chase, entitled "Present-Day Knowledge of Metals and the Engineer," in the September 9, 1916, issue of SCIENTIFIC AMERICAN SUPPLEMENT has been brought to my attention. In this article the following statement appears, which should be corrected:

"A total of 3,000,000 pounds of such material (wrought and cast manganese brass) was used (on the Catskill aqueduct) at a cost of about $1,000,000. A great part of it has had to be replaced since with other materials, and the balance is under suspicion because of the development of 'season cracking,' a form of progressive failure associated with high internal stresses caused by improper methods of manufacture, or caused by subjection to high unit-stresses under corrosive conditions."

Of the approximate total of 3,000,000 pounds of brass (bronze so-called) used on the Catskill aqueduct, about 2,000,000 pounds are castings and 450,000 pounds are large forgings, principally stems for sluice-gates and valves of large sizes. The remainder consists largely of rolled, extruded and drawn rods, bars and pipes for bolts, ladders, piping and similar parts. Very severe tests and critical observation have developed no troubles with the castings other than those due to bad foundry practice or accidents common to foundry work. No defects have been discovered in the large forgings.

The troubles to which some publicity has been given have been confined almost entirely to the wrought articles, but these articles, although they constitute a relatively small proportion of the total weight, are very numerous, and from the nature of their uses defects in them have been annoying and costly out of proportion to the money value of these parts themselves. Actual failures, although many, among these latter objects, have been a small proportion of the total, but sufficient to cast suspicion on all. Because of the importance of these pieces, the difficulty of future inspection and renewal, and the lack of any dependable method for differentiating metal which would develop defects from that which would remain perfect in service, bolts, ladders, piping and similar objects have been quite generally replaced by steel or copper, or reinforced in some way. The principal castings and large forgings, a total of about 2,500,000 pounds, remain in service, and after severe tests are regarded as wholly dependable. Only a portion of one sixth of the total weight of brass (bronze) purchased for the Catskill aqueduct has given trouble.

It should be stated, also, that the failures of wrought bronze articles like bolts and ladders, have not been confined to manganese bronze, or to the product of any one maker of manganese bronze. There have been failures in several brands of manganese bronze, in Naval brass and Tobin bronze.

As to the author's assertion that "there was enough information on the subject of brass to have warned against many of the bad mill and foundry practices that were permitted," it is only necessary to state that both the United States Navy Department and the Panama Canal Commission experienced troubles similar to those of the Board of Water Supply during the period of the construction of the Catskill aqueduct and that the Navy Department made changes designed to prevent such troubles about the same time as the Board of Water Supply took steps to exclude unreliable material. While the so-called "season cracking" often occurred, the cause of this type of failure of brass was not understood nor widely known at the beginning of the aqueduct work. It is only during the last two years that any appreciable progress has been made towards the explanation of this fact. A thorough investigation, begun about three years ago by the Bureau of Standards, Department of Commerce, Washington, has added to the knowledge of the subject and is still in progress.

ALFRED D. FLINN, Deputy Chief Engineer.
Board of Water Supply, New York.

Locomotion and Behavior of Sea-Anemones*

By G. H. Parker

ALTHOUGH sea-anemones belong to a group of animals characterized by radial symmetry, they have long been known to exhibit a bilateral arrangement in their mesenteries and adjacent parts. Most bilateral animals move in definite relations to their axis of symmetry. Is this true of sea-anemones?

Single specimens of Actinia or of Sagartia will creep now in the direction of their planes of symmetry, now at any angle to those planes and thus demonstrate the entire independence of the direction of locomotion and the axis of symmetry. This is especially clearly seen in Sagartia, which will creep away from a source of light irrespective of the relation momentarily called forth between the direction of locomotion and the animal's structural axis. Locomotion in sea-anemones is therefore a radial operation performed by the radial pedal disk and not necessarily associated with the more or less bilateral oral disk.

Locomotion is accomplished by a wave-like movement that progresses over the pedal disk in the direction of locomotion. In a specimen of Sagartia with a pedal disk of about 4 millimeters in diameter, the locomotor wave coursed over the disk in an average time of 1.65 minutes and with each wave the animal progressed on the average 1.2 millimeters. In a large sea-anemone, Condylactis, with a pedal disk 130 by 80 millimeters, the passage of a locomotor wave required on the average three minutes and the animal progressed for each wave on the average 11.4 millimeters.

In the locomotion of sea-anemones each part of the pedal disk is successively raised from the substratum, moved forward, and put down. The attachment to the substratum is due chiefly to adhesion heightened by the secretion of a thick slime rather than to a sucker-like action of the pedal disk. The mechanism of locomotion consists of the circular muscle of the pedal disk, the basilar muscles, and the longitudinal muscles of the mesenteries, all of which act on the fluid-filled spaces in the pedal region. The pressure thus generated is not above 6 centimeters of water.

Specimens of Sagartia from which the oral disk has been cut off will creep in an essentially normal manner, for instance, away from a source of light. Hence the pedal portion of a sea-anemone, like its tentacles, must contain a neuromuscular mechanism sufficient for the activity of that part of its body.

The older students of sea-anemones, such as Gosse and von Lendenfeld, believed that these animals were endowed with mental traits not unlike those of man. Later workers, such as Loeb, Jordan, and others, regard these forms as finely adjusted machines devoid of psychic attributes. To discover something of the nervous nature of these animals two forms of their behavior were studied in detail, the appropriation of food, and general retraction. The work was carried out for the most part on Metridium and Sagartia.

In the appropriation of food, the parts chiefly concerned are the five following: the tentacular gland cells whereby the tentacles are rendered adhesive for food, the tentacular muscles by which the tentacles are pointed toward the mouth, the tentacular cilia by which the food is delivered from the tip of the tentacle to the mouth, the transverse mesenteric muscles whose action opens the mouth, and the oral cilia (lips and oesophagus) whose reversal in the presence of food carries this material into the digestive cavity of the sea-anemone. Of these five parts the mucous cells, the tentacular cilia, and the transverse mesenteric muscles are so uniform in their action that they need no further consideration. The oral cilia and the tentacular muscles on the other hand are much more open to variation and hence may serve to indicate to some extent the condition of the animal as a whole.

The oral cilia after having reversed their effective stroke in the presence of food a number of times, eventually cease to show this change, a condition supposed to be due to altered metabolism as a result of feeding. But this same cessation occurs when the oral membranes are cut from the animal and worked with separately. It is strictly local in its appearance and probably a pure fatigue effect.

The feeding movements of the tentacles, though also modified by fatigue, have been supposed to show changes of a more significant kind. If the tentacles on one side of the animal are much exercised, those of the other side decrease in responsiveness. This change has also been supposed to be due to changed metabolism, but, since it appears quickly and before a general metabolic change can have occurred, it is probable that this, too, is the result of fatigue in that the food juices from the cavity of the tentacles transfuse the walls of these organs and thus reduce the sensitiveness of their exterior. Thus none of the elements in the feeding responses of sea-anemones imply that these animals are organisms that respond as firmly united wholes.

Retraction, whereby the more delicate parts of the sea-anemone are drawn in and covered, is the commonest protective act of this animal. Expansion is the reverse of retraction and puts the animal in form for full activity. Vigorous mechanical stimulation, most chemical stimuli, strong light, and high temperature induce retraction. The presence of food in the adjacent water, and water currents induce expansion. Oxygen as such seems to have little effect on these reactions.

Sagartia retracts when left dry by the tide and expands when it is again covered by the returning water. Metridium retracts in bright daylight and expands at night. The tidal rhythm of Sagartia and the nychthemeral rhythm of Metridium are not retained after the rhythmic stimulus is removed as has been claimed for European species by Bohn. There is also no evidence of an anticipatory reaction to the tides as maintained by Piéron. The retraction and expansion of sea-anemones, therefore, give no support to the view that these animals act under highly specialized nervous states.

The form of response which more than any other involves a sea-anemone as a whole is creeping. But even this form of activity can be accomplished by the pedal half of the animal. To repeated stimuli sea-anemones quickly adjust themselves rather by a process of adaptation than by one of exhaustion. Yet they have been found to show no evidence of associative capacity. They are animals whose momentary conditions are dependent upon the combined stimuli of their immediate surroundings rather than forms that are greatly influenced by their past history. And in consequence of this their unity is not of a pronounced type. They are more in the nature of a sum of parts than they are organic units such as we are familiar with among most of the higher animals.

The extended paper will be published in the *Journal of Experimental Zoology*.

*Proceedings of the National Academy of Sciences.

Healthy Animals Carry Diphtheria Germs

IT has already been remarked that certain epidemics of diphtheria, which arise without apparent cause, can be traced to animals, and generally to birds or especially domestic fowls. In this case the diphtheria is often due to the hoeffler bacillus, but can arise from other and apparently harmless microbes. Were the effect due to really diseased animals or fowls it would be an easy matter to take the proper measures, but unfortunately this is not the case, for the diphtheria bacillus can be found in the throat mucus of healthy animals as well as in the cloacal mucus of birds or fowls. According to Dr. Gourrin, to the salivary secretions of domestic fowls we must add those of animals such as rabbits, dogs, horses, cattle and other domestic animals. While these germs are not virulent in the animals, they quickly become so when they enter the human system, and the fact that healthy animals can possess such germs will amply suffice to explain the mysterious appearance of certain human epidemics. The remedy is not far to seek, and this is to prevent children from having undue contact with domestic animals, such as kissing them or having contact with the animals' tongue, such as licking or by feeding out of the hand. While this may be a privation, due attention must be paid to the importance of the question. Also avoid the dissemination of manure in which fowls peck or dogs and cats may rummage, and keep manure of all kinds coming from domestic animals well out of the way in separate places, so that the animals cannot seek their food in it. These precautions are to be especially observed during periods of epidemics, but hold good, of course, at all times. Where epidemics prevail among fowls, the healthy ones should be separated at once, and the others incinerated if in limited number, or at least treated with the proper serum.

Many curious tools are used by the carver.

A Japanese saw is used for cutting off disks of ivory.

One of the Curious Trades of New York

ALTHOUGH there are very many specimens of artistic objects in carved ivory from Japan owned in this country little original work of this kind has been produced here until quite recently; but many of these delicate pieces of workmanship become injured through accidents and the ravages of time, and repairs and restorations are required that have been inconvenient to meet. For this reason a number of skilled Japanese artisans have found it profitable to establish themselves in New York, where there is quite a constant demand for their services. Repairs, however, do not occupy all of the time of these artists, and much of their skill is devoted to the production of original creations in carved ivory and special designs, for which commissions are not infrequent.

The accompanying illustrations show the men at their benches, engaged in the delicate work of carving, which is almost wholly accomplished by hand tools, keen cutting implements of various shapes being employed. In one picture the workman is shown cutting discs of ivory from an elephant tusk, using a Japanese hand saw that appears strange in shape to us, in comparison with a similar American saw, which can be seen in the same picture, alongside of other native tools of unusual appearance, but which these workmen wield with great skill.

The carving of ivory, however, is not the only work carried on in this unique little shop, for the clever craftsmen who conduct it are masters of many trades, and are frequently called upon to effect the restoration of many different kinds of curios and objects of art, and undertake with equal facility the repair of ancient Japanese figures as well as those of European make, involving work in lacquer, metals and wood; and in one illustration is seen an ancient head of Buddha, said to be 1,200 years old, which is awaiting renovation.

This little shop is but one of a great number in the great metropolis where curious and unusual trades are carried on, but it would be difficult to find one that is more novel and interesting in the character of its activities.

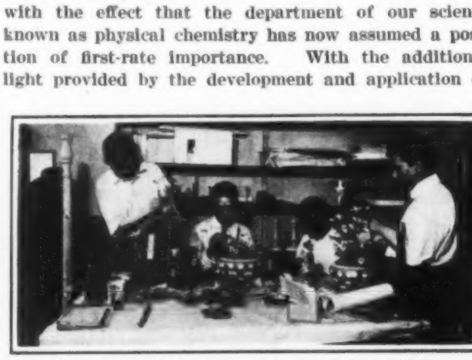
The Progress of Chemistry*

By Prof. G. G. Henderson, D.Sc., LL.D., F.R.S.

THE period which has elapsed since the last meeting of the section in Newcastle has witnessed truly remarkable progress in every branch of pure and applied chemistry. For fully fifty years previous to that meeting the attention of the great majority of chemists had been devoted to organic chemistry, but since 1885, or thereabouts, while the study of the compounds of carbon has been pursued with unflagging energy and success, it has no longer so largely monopolized the activities of investigators. Interest in the other elements, which had been to some extent neglected on account of the fascinations of carbon, has been revived with the happiest results, for not only has our knowledge of these elements been greatly extended, but their number also has been notably increased by the discovery of two groups of simple substances possessed of new and remarkale properties—the inert gases of the argon family and the radio-active elements. In addition, the bonds between mathematics and physics on one hand

Carving a cover for the jar seen in the front page illustration.

and chemistry on the other have been drawn closer, with the effect that the department of our science known as physical chemistry has now assumed a position of first-rate importance. With the additional light provided by the development and application of



Many demands are made on the art shop.

physico-chemical theory and methods, we are beginning to gain some insight into such intricate problems as the relation between physical properties and chemical constitution, the structure of molecules and even of atoms, and the mechanics of chemical change; our outlook is being widened, and our conceptions rendered more precise. Striking advances have also been made in other directions. The extremely difficult problems which confront the biochemist are being gradually overcome, thanks to the indefatigable labors of a band of highly skilled observers, and the department of biological chemistry has been established on a firm footing through the encouraging results obtained within the period under review. Further, within the last few years many of our ideas have been subjected to a revolutionary change through the study of the radio-active elements.

The more purely scientific side of our science can claim no monopoly in progress, for applied chemistry, in every department, has likewise advanced with giant strides, mainly, of course, through the application of the results of scientific research to industrial purposes. Many of the more striking results in the field of modern chemical industry have been obtained by taking advantage of the powers we now possess to carry out operations economically both at very high and at very low temperatures, and by the employment on a manufacturing scale of electrolytic and catalytic methods of production. Thanks largely to the invention of the dynamo, the technologist is now able to utilize electrical energy both for the production of high temperatures in the different types of electric furnace and for electrolytic processes of the most varied description. Among the operations carried out with the help of the electric furnace may be mentioned the manufacture of graphite, silicon, and phosphorus; of chromium and other metals; of carbides, silicides, and nitrides; and the smelting and refining of iron and steel. Calcium carbide claims a prominent place in the list, in the first place because of the ease with which it yields acetylene, which is not only used as an illuminant, and, in the oxy-acetylene burner, as a means of producing a temperature so high that the cutting and welding of steel is now a comparatively simple matter, but also promises to serve as the starting-point for the industrial synthesis of acetaldehyde and many other valuable organic compounds. Moreover, calcium carbide is readily converted in the electric furnace into calcium cyanamide, which is employed as an efficient fertilizer in place of sodium nitrate or ammonium sulphate, and as a source of ammonia and of alkali cyanides. Among the silicides carborundum is increasingly used as an abrasive and a refractory material, and calcium silicide, which is now a commercial product, forms a constituent of some blasting explosives. The Serpek process for the preparation of alumina and ammonia, by the formation of aluminium nitride from bauxite in the electric furnace, and its subsequent decomposition by caustic soda, should also be mentioned. Further, the electric furnace has made possible the manufacture of silica apparatus of all kinds, both for the laboratory and the works, and of alundum ware, also used for operations at high temperature. Finally, the first step in the manufacture of nitric acid and of nitrites from air, now in operation on a very large scale, is the combustion of nitrogen in the electric arc.

In other industrial operations the high temperature which is necessary is obtained by the help of the oxy-hydrogen or the oxy-acetylene flame, the former being

*Extracts from a paper read at the annual meeting of the British Association for the Advancement of Science, at Newcastle. From a report in *Nature*.

Restoring figure of a warrior 800 years old.

Repairing an old figure of European make.

WHEN NOT ENGAGED IN CARVING THESE CLEVER ARTISANS TURN THEIR HANDS TO THE RESTORATION OF ALL KINDS OF CURIOS.

used, amongst other purposes, in a small but, I believe, profitable industry, the manufacture of synthetic rubies, sapphires, and spinels. Also, within a comparatively recent period, advantage has been taken of the characteristic properties of aluminum, now obtainable at a moderate price, in the various operations classed under the heading alumino-thermy, the most important being the reduction of refractory metallic oxides, although, of course, thermite is useful for the production of high temperatures locally.

The modern methods of liquefying gases, which have been developed within the period under review, have rendered possible research work of absorbing interest on the effect of very low temperatures on the properties and chemical activity of many substances, and have been applied, for instance, in separating from one another the members of the argon family, and in obtaining ozone in a state of practical purity. Moreover, industrial applications of these methods are not lacking, amongst which I may mention the separation of nitrogen and oxygen from air, and of hydrogen from water-gas—processes which have helped to make these valuable elements available for economic use on a large scale.

Electrolytic methods are now extensively employed in the manufacture of both inorganic and organic substances, and older processes are being displaced by these modern rivals in steadily increasing number. It is sufficient to refer to the preparation of sodium, magnesium, calcium, and aluminium, by electrolysis of fused compounds of these metals; the refining of iron, copper, silver, and gold; the extraction of gold and nickel from solution; the recovery of tin from waste tin-plate; the preparation of caustic alkalis (and simultaneously of chlorine), of hypochlorites, chlorates, and perchlorates, of hydrosulphites, of permanganates and ferricyanides, of persulphates and percarbonates; the regeneration of chromic acid from Chromium salts; the preparation of hydrogen and oxygen. As regards organic compounds, we find chiefly in use electrolytic methods of reduction, which are specially effective in the case of many nitro-compounds, and of oxidation, as, for instance, the conversion of anthracene into anthraquinone. At the same time a number of other compounds, for example, iodoform, are also prepared electrolytically.

Within recent years there have been great advances in the application of catalytic methods to industrial purposes. Some processes of this class have, of course, been in use for a considerable time, for example, the Deacon chlorine process and the contact method for the manufacture of sulphuric acid, whilst the preparation of phthalic anhydride (largely used in the synthesis of indigo and other dyestuffs), by the oxidation of naphthalene with sulphuric acid with the assistance of mercuric sulphate as catalyst, is no novelty. More recent are the contact methods of obtaining ammonnia by the direct combination of nitrogen and hydrogen, and of oxidizing ammonia to nitric acid—both of which are said to be in operation on a very large scale in Germany. The catalytic action of metals, particularly nickel and copper, is utilized in processes of hydrogenation—for example, the hardening of fats, and of dehydrogenation, as in the preparation of acetaldehyde from alcohol, and such metallic oxides as alumina and thoria can be used for processes of dehydration—*e.g.*, the preparation of ethylene or of ether from alcohol. Other catalysts employed in industrial processes are titaneous chloride in electrolytic reductions and cerous sulphate in eletrolytic oxidations of carbon compounds, gelatine in the preparation of hydrazine from ammonia, sodium in the synthesis of rubber, etc.

Other advances in manufacturing chemistry include the preparation of a number of the rarer elements and their compounds, which were scarcely known thirty years ago, but which now find commercial applications. Included in this category are titanium, vanadium, tungsten, and tantalum, now used in metallurgy or for electric lamp filaments; thoria and ceria in the form of mantles for incandescent lamps; pyrophoric alloys of cerium and other metals; zirconia, which appears to be a most valuable refractory material; and compounds of radium and of mesothorium, for medical use as well as for research. Hydrogen, together with oxygen and nitrogen, are in demand for synthetic purposes, and the first also for lighter-than-air craft. Ozone is considerably used for sterilizing water and as an oxidizing agent; for example, in the preparation of vanillin from isoeugenol, and hydrogen peroxide, now obtainable very pure in concentrated solution, and the peroxides of a number of the metals are also utilized in many different ways. The per-acids—perboric, percarbonic, and persuhphuric—or their salts are employed for oxidizing and bleaching purposes, and sodium hydrosulphite is much in demand as a reducing agent—*e.g.*, in dyeing with indigo. Hydroxylamine and hyrazine are used in considerable quantity, and the manufacture of cyanides by one or other of the modern methods has become quite an important industry, mainly owing to the use of the alkali salts in the cyanide process of gold extraction. Those remarkable compounds, the metallic carbonyls, have been investigated, and nickel carbonyl is employed on the commercial scale in the extraction of the metal. Fine chemicals for analysis and research are now supplied, as a matter of course, in a state of purity rarely attained a quarter of a century ago.

In the organic chemical industry similar continued progress is to be noted. Accessions are constantly being made to the already enormous list of synthetic dyes, not only by the addition of new members to existing groups, but also by the discovery of entirely new classes of tinctorial compounds; natural indigo seems doomed to share the fate of alizarine from madder, and to be ousted by synthetic indigo, of which, moreover, a great number of useful derivatives are also made.

Synthetic drugs of all kinds—anti-pyrine and phenacetin, sulphonal and veronal, novacain and β-eucaine, salol and aspirin, piperazine and adrenaline, atoxyl and salvarsan—are produced in large quantities, as also are many synthetic perfumes and flavoring materials, such as ionone, heliotropine, and vanillin. Cellulose in the form of artificial silk is much used as a new textile material, synthetic camphor is on the market, synthetic rubber is said to be produced in considerable quantity; and the manufacture of materials for photographic work and of organic compounds for research purposes is no small part of the industry.

Cocoanut Products and Other Substitutes for Butter

In his report presented to the Council of Hygiene, M. Leon Lindet treats of the question of alimentary fats, including butter or its various substitutes, also different oils, with special reference to the prevailing conditions in France. Because of the high price of butter just now it is desired to introduce as many substitutes for it as possible, and especially the ones that can be had for a reasonable price. Among others he speaks of the vegetable oils, and it is to be noted in passing that in the south of France cooking is done almost exclusively with olive oil, also with arachide and cotton seed oil, and the like. But the main interest as regards substitutes for butter outside of margarine appears to lie in the use of cocoanut oil or grease, and within the last few years such products have been introduced for popular consumption under the names of "vegetaline," "cocose," and others. The raw cocoa material known as *coprah*, comes to Europe in the dried state and the oil pressing is done here. This gives some 60 to 65 per cent of oil, which is then put through a soda and other chemical treatment and then de-odorized, giving an excellent fat product which is solid at the usual temperature, but its melting point is much below that of butter, *i.e.*, 25 or 26 compared with 33 to 35 deg. C., so that this often leads to the addition of a certain percentage of fats which have a higher melting point, such as Karité or Mowhra, colonial products, or the more solid part of cotton seed oil. All these fat products used as a substitute for butter have a high alimentary value. Cocoanut fats as well as natural butter are more digestible than suet fats or margarine, which may compensate for the lower percentage of carbon which the latter contain. But all these products can be readily digested by healthy persons, hence no special consideration need be paid to this point or, on the other hand, to their chemical composition. As regards weight comparisons, while the melted products do not contain water, it is not the same for natural suet fats, nor for margarine. This latter contains 5 to 6 per cent of water, and natural butter has as much as 18 per cent, so that this must be considered when it comes to the economic side. On the whole, any of the present substitutes can be recommended as regards alimentation as well as hygiene.

Hydrogen for Military Purposes*

Facts Relating to Its Production, and Processes in Use

By Edward D. Ardery[1]

ONE thousand cubic feet of hydrogen will lift about 70 pounds; the same volume of coal gas about 35 pounds. According to the purity of the hydrogen, its lifting capacity varies. One process gives gas with a lifting power of about 1.19 kilograms per cubic meter, another 1.183 kilograms, another from 1.175 to 1.195 kilograms.

The ascensional force of gases depends upon their specific gravity, temperature, and the barometric pressure of the atmosphere. The ascensional force of any gas equals the weight of air minus the weight of an equal volume of the gas. Hydrogen has twice the ascensional force of pure coal gas, and is universally used for military balloons. Hydrogen permits the employment of smaller balloons, which facilitates transportation and rapid filling, besides affording a smaller target at which the enemy may shoot.

For military purposes, however, hydrogen would find its greatest use in inflating balloons, either captive or free. To generate the hydrogen gas readily and in sufficient quantities, recourse has been had to various processes. Probably the first method used consisted in employing iron filings and dilute sulphuric acid. In this process the iron filings should be free from rust, and the gas evolved should be cleaned by passing through a water seal and lime purifier. The reaction is given by the formula:

$$Fe + H_2SO_4 = FeSO_4 + H_2$$

Similarly, zinc may be used instead of iron. The gas from zinc and sulphuric acid is purer than when iron is used. 100 pounds of sulphuric acid and about 140 pounds of zinc give 1,000 cubic feet of hydrogen. A balloon with a capacity of 16,000 cubic feet would thus require about two tons of these materials.

In the Russo-Japanese War the Russians used a process based on the action of aluminum on sodium hydroxide. This method presupposes an ample water supply, and has the drawback that it requires 5½ kilograms of materials for every cubic meter of hydrogen produced. The apparatus consisted of sheet metal containers, each of which was partly filled with sodium hydroxide. The aluminum chips were held in a gauze drum, a portion of which rested in the liquid. From the producer, the gas passed through the washer and from there to the balloon.

In the Morocco campaign, the Spanish government used a producer developed by Schuckert & Co. Instead of using aluminum, silicon was employed. At temperatures of from 80 deg. to 90 deg. Cent. the action of this element on sodium hydroxide is energetic. The temperature need not be attained by the use of fuel if the natural development of heat during the solution of the caustic soda in water, while forming the solution, is utilized. Preparations for starting the generator consist merely in pulverized caustic soda being poured during stirring into a vessel containing water, thus getting a solution of 90 deg. Cent. in temperature. By turning on a cock this solution is admitted to the generator vessel, and silicon is added. During the formation of the gas, which lasts about 50 minutes, water is again run into the dissolving vessel, and caustic soda in pieces added, which quickly dissolves with the aid of the hot hydrogen touching the sides of the solution vessel.

This enables a new cycle to be commenced with only a few minutes interruption, at the end of every generating process. When the formation of gas is finished, the generator contains a solution of water-glass, a non-injurious liquid, which can be let out without special precaution. The temperature reached does not exceed 110 deg. Cent. The apparatus is made of iron, and not being subject to chemical or mechanical destruction, it is of practically unlimited durability.

The French have used ferro-silicon instead of silicon. The producing apparatus is called "Silicol." Another method originated by the French is called the "Hydrogenit" process. This is particularly adapted for use where an abundance of water is not available. "Hydrogenit" is a mixture of finely powdered ferro-silicon and sodium-calcium oxide. It is a gray, sandy substance, which, even in a closed receptacle, burns with a large production of hydrogen. The mixture is ignited by means of a match or a small amount of ignition powder. It comes in sheet metal containers, and is said to keep indefinitely at normal temperatures. These containers are placed bodily in the producer and fired. The producer is surrounded by a water jacket, the contents of which are eventually converted into steam. Towards the end of the process, the steam is shot into the chamber to accelerate the action. The gas is washed in water and then dried by passing through screens of sawdust and coke.

Calcium hydride, a substance known commercially as "Hydrolith" (CaH_2), if dropped into water, evolves hydrogen rapidly.

$$CaH_2 + 2H_2O = Ca(OH)_2 + 2H_2$$

The objection to it is its excessive cost. A sodium base may be used instead of calcium, but great care is necessary to prevent ignition of the hydrogen by the heat of the chemical reaction. "Hydrone" is another substance that requires only the addition of water to produce hydrogen.

A German corporation has perfected the old method of producing hydrogen by passing steam over red-hot iron filings. The steam is dissociated, the oxygen combining with the hot iron to form black oxide of iron (Fe_3O_4), leaving hydrogen free. The iron is then regenerated by blowing over the oxide hot water-gas containing a large percentage of carbon monoxide. The black oxide gives up oxygen and is reduced to spongy iron. The process may be made continuous by using two ovens.

In manufacturing nitrogen and oxygen from the air, low temperatures are employed, but these temperatures are not low enough to effect the sparation of hydrogen from water gas. Water gas consists of about 50 per cent of hydrogen, carbon monoxide, and some nitrogen. It also contains a comparatively small percentage of CO_2, which is first eliminated by passing the gas over caustic potash. The gas thus purified is compressed to about 30 atmospheres, and cooled to a temperature in the neighborhood of the boiling point of oxygen, say —200 deg. Cent. The liquefiable constituents are the CO and N, whose critical temperatures are, respectively, —136 degrees and —146 deg. Cent. When allowed to escape from an open valve at the temperature of its surroundings, hydrogen, however, does not cool, but rises in temperature. Thus the regenerative method applied in the liquefaction of air is not applicable for cooling down water gas. Liquid air is therefore resorted to, the requisite degree of cold being obtained by allowing it to evaporate. In spite of the efforts to eliminate CO_2 and water vapor, traces of these bodies pass into the separating apparatus and are deposited there in solid form, ultimately obstructing it after the lapse of a certain time. By having duplicate plants, one can be worked while the other is brought back into working shape by heating it and blowing gas through it.

The Signal Corps of the U. S. Army has made experiments with a view to obtaining hydrogen by refrigerating illuminating gas.

A method invented by two Dutch engineers is used both in Germany and in Russia. This process uses the gas produced by the fractional distillation of crude oil and tar. The gas is passed through a layer of hot coke, whereby the hydrocarbons break up with ultimate liberation of hydrogen. The product delivered contains from 2 to 3 per cent of CO, which is removed by subsequently treating with hot sodium oxide. Oil-gas, crude oil, petroleum by-products, tar, benzol, or benzine may be employed in the same process. Charcoal can be used instead of coke. The oil, which has been previously heated, is introduced as a spray at the top of the producer. The coke is brought to a white heat by a hot-air blast. As the oil eventually cools the coke, production is intermittent.

Hydrogen is also a by-product in the electrochemical manufacture of caustic soda and sodium from sodium chloride.

Hydrogen may be obtained from the electrolysis of water by using lead electrodes and a dilute sulphuric acid electrolyte, or iron electrodes and a 10 to 20 per cent solution of potash. If a solution of KOH is used, electrolysis causes the oxygen to combine with the anode, while hydrogen is liberated at the cathode. At intervals the decomposed water has to be renewed, while the potash remains in solution, and there is practically no loss. The electromotive force required is about 3 volts per cell.

Our army installed a plant at Fort Omaha, Nebraska, for generating hydrogen by the electrolysis of water. Thirty cells were used. 1,500 amperes of direct current were passed through the cells in series. The voltage varied from 85 to 120, depending on the internal resistance of the cells.

In the original electrolytic plants each cell formed an independent unit, and had with the others a positive and a negative connection, and, furthermore, a separate pipe line for hydrogen and for oxygen. The filter press system of Sürth came into use about eight years ago. The Sürth system is used extensively by Germany for military purposes. The apparatus consists of a number of cells forming at once the electrodes and the storage tank for the electrolyte. The cells are composed of a special metal which is attacked by neither the oxygen, alkali, nor electric current. These cells are pressed together and form a hermetically closed tank. The electrodes are connected in series. The separation of the gases formed is effected by means of special asbestos tissue. This tissue is placed between the anode and cathode, and separates them positively from each other. At the same time, it permits an easy passage for the electrolyte, and insulates both electrodes from each other. In this manner they form a bipolar electrode; that is, they are positive at one side and negative at the other. Each electrode has in its upper part two connecting canals. One of them has the connection to the positive side and the other has a connection to the negative side, so that all oxygen goes in one canal and all hydrogen in the other. The whole apparatus is filled with electrolytic solution. In the interior of the apparatus there is no accumulation of gas. The electric current goes through the whole apparatus and develops on the surface of each electrode the corresponding gas. For an apparatus of 180 to 200 cells there is provided only one draw-off for hydrogen and one for oxygen. There is only one intake for water. Electrodes that have been working four years have shown no sign of wear.

Hydrogen gas from oil-gas is about 98.4 per cent pure, with a specific gravity (air = 1) of 0.087 to 0.092. From water gas the hydrogen is 97 to 97½ per cent pure; but if this be passed over soda-lime the resulting gas contains as its only impurity 0.6 to 0.8 per cent of nitrogen. A percentage of 97 to 97½ hydrogen corresponds to a density of 0.094, while when the percentage of hydrogen is raised to 99.2 or 99.4, the density falls to 0.077. Schuckert's metallic silicon process gives hydrogen at least 99 per cent pure and free of poisonous or injurious admixtures. The Sürth electrolytic process gives gas 99.8 per cent pure.

Stationary plants, usually providing for generation on a large scale, must necessarily be designed along lines more economical than for portable plants. Stationary plants would find use at aeronautic establishments, army centers, and at points where gas is generated to be compressed into cylinders for shipment. Stationary plants may have capacities for generating 300 cubic meters and upwards per hour. The smaller sizes of apparatus would probably weigh about 4,000 kilograms net, or 5,500 kilograms packed for ocean shipment; the larger sizes, 9,500 kilograms net, and 12,000 kilograms gross, no piece weighing over 2,000 kilograms. The electrolytic plant installed at Fort Omaha in 1908 had a capacity of 3,000 cubic feet (85 cubic meters) per hour. To follow an army's movements, portable plants are necessary. These should permit of being mounted on cars or wagons. Some plants can be set up on shipboard, some on three or fewer railroad cars, and others on wagons. The capacity of portable plants varies from 9 cubic feet (0.25 cubic meters) per hour to (56,500 cubic feet) 1,600 cubic meters per hour.

The weights of portable plants depend, of course, on the capacity and type of plant. Schuckert's generator cars weigh about 2,000 kilograms each, and the scrubber cars about 1,700 to 2,100 kilograms.

In comparing the relative cost of portable plants and stationary plants distributing by means of steel tubes, consideration should be given to the cost of the tubes, their weight to be transported, and the cost of compressing the gas.

For transporting in campaign, hydrogen may be absorbed by some chemical substance dissolving it or giving with it a combination capable of restoring it easily and rapidly whenever wished. Hydrolith and hydrone

*A paper read before the New York Section of the American Electrochemical Society in joint session with the American Chemical Society and Society of Chemical Industry.

[1]Captain, Corps of Engineers, United States Army.

are in this class. Or, the gas may be compressed in steel tubes. Some French tubes are about 4 meters long, 270 millimeters interior diameter, and 9 millimeters thick. Other dimensions are used at sea and in the colonies. In order to avoid explosions, tubes have been tried with diameters of 45 to 400 millimeters.

Our service employs cylinders about 7 feet (2 meters) long, and 5½ inches (14 centimeters) in diameter; and also some about 4 feet (1.2 meters) long and 8½ inches (22 centimeters) in diameter. They are made of cold drawn seamless steel tubing.

The weight of steel cylinders is less than the weight of the iron and sulphuric acid necessary to produce an equal volume of hydrogen. The weight of our tubes does not exceed 100 pounds (45 kilograms) each. In the French service, each wagon carrying tubes weighs 3,000 kilograms for about every 15 kilograms of gas transported, or about 200 times the weight of the hydrogen. They contain 200 liters of gas at 133 kilograms pressure; equivalent to about 25 cubic meters at atmospheric pressure. The German flasks hold about 36 liters of gas at a pressure of 130 atmospheres, which corresponds to about 5 cubic meters of balloon space. Some American flasks contain 100 and 200 cubic feet (3 to 6 cubic meters). In some cases compression is done at from 150 to 200 atmospheres (2,200 to 2,940 pounds per square inch). Pressures as low as 700 pounds (47 at.) have been used, to prevent explosion. Tanks used in welding or cutting are charged to about 100 or 150 pounds (7 to 10 at.). In our service the tubes are tested with hydraulic pressure up to about 5,000 pounds (340 at.) and are charged to about ½ of the pressure used in testing. All our cylinders have a safety outlet blowing at 3,500 pounds (238 at.). Our 7 feet by 5½ inches (2 meters by 14 centimeters) tubes have a capacity of about one cubic foot (28 liters) and are ordinarily charged to 120 atmospheres.

For German conditions it has apparently been found that the best method of bringing gas to the balloons is not to bring the producer to the front, but to send forward the hydrogen in steel flasks. The flasks are transported in caissons, 20 to each vehicle, and it is so arranged that six caissons can be coupled together when the balloon is to be filled. The French have some wagons that carry six tubes. The transportation of hydrogen in steel tubes is quite an old practice. The English have used tubes since 1882; the Italians, since 1887.

The Germans fill a 600 cubic meter balloon from 120 flasks in about 20 minutes. Using oil gas for producing hydrogen requires one to two hours to fire up. According to the size of the plant being used, Schuckert's metallic silicon process allows of a full production of hydrogen to be reached in from 10 to 45 minutes from the time the command is given. Other processes require different periods of time before gas becomes available for inflation; so the compressed gas in flasks has a considerable advantage as far as the time factor is concerned. Their two principal objections are the danger of explosion and the dead weight to be carried.

A pipe line for carrying hydrogen is in successful operation in Germany. The line is 4½ kilometers long, and can supply 1,000 cubic meters of gas daily. This requires a pressure of 1,000 millimeters (water column). It discharges into a storage tank. The joints of the pipe are welded autogeneously for most of the length, unions being installed at long intervals.

The cost of production varies, of course, with the size of the plant, market and labor conditions, and the process used. Some of the *alleged* costs per cubic meter (35 cubic feet) of hydrogen gas, according to the process used, are: Ferro-silicon 20 cents, hydrogenit 32 cents, hydrolith 100 cents, steam and hot iron filings 3 cents, distillation of crude oil and tar 3½ cents, water gas 25 cents, old method of iron and sulphuric acid 25 cents, calcium hydride 175 cents, silicon and caustic soda 210 cents. By electrolysis, 1,500 amperes produce 23 cubic feet (0.66 cubic meters) of hydrogen and 11½ cubic feet (0.33 cubic meters) of oxygen per cell per hour.

As I have shown above, the lifting power of a balloon depends on the gas used to inflate it and on the volume of the balloon. The temperature and barometric pressure of the atmosphere affect the density of the gas, and hence its ascensional force. A captive spherical balloon cannot be used when the wind is greater than twenty miles an hour.

The usual fixed balloon has a capacity of 600 cubic meters. The dirigible balloons have capacities up to possibly 60,000 cubic meters. It is stated that the German dirigible that descended in France in 1913 had a volume of 20,000 cubic meters and a lifting capacity of 20 tons. The normal working internal pressure is understood to be 2 ounce per square inch (0.0085 atmosphere). Cotton, silk, goldbeater's skin, and various rubberized fabrics have been used as balloon envelopes. Silk is objectionable on account of its cost, and on account of its accumulating static electrical charges. Great Britain has used goldbeater's skin. Rubberized fabrics oxidize and crack. The envelope should be strong, elastic, impermeable to gas, water repellant, and of light weight. Chlorine attacks balloon envelopes.

Hydrogen is so light that in case of leaks, even low down in the envelope, the gas rises; but if mixed with air in a balloonet it becomes heavier, descends, and may be exploded by a spark from the engine.

Without going into the theory of ballooning, I might add that unless the balloon envelope is elastic, a rise in altitude of 125 feet (38 meters), or a rise in temperature of the gas of 2½ deg. Fehr. (1.4 deg. Cent.) necessitates the loss of gas. Goldbeater's skin allows a rise to 2,000 feet without loss of gas. As fuel is used up or explosives dropped, the tendency of the lightened balloon is to rise, thus probably causing a loss of gas. In dirigibles, it must be borne in mind that ordinarily there is sufficient lifting capacity only when the motors are running. If they stop, the vessel must descend or jettison some ballast.

A trip of about 8½ hours from a base in Germany to the English coast would mean the use of about 1½ tons of fuel. If 1½ tons of explosives are carried, a state of static equilibrium will have been attained by the time the coast is reached.

The hitherto too rapidly fluctuating buoyancy of the airship may now be controlled through the use of the graduated motor exhaust, which is evenly distributed by ducts throughout the entire air-jacket between the outer and inner hulls, and the same system enables the passing of hot and cold currents through the air-jacket at the will of the operator. These alternate hot and cool currents expand or contract the gas, producing rapid ascent or descent. This device has assured a static gas, which maintains the airship for long periods at normal buoyancy.

If the air-jacket contains a charge of nitrogen gas, this not only insulates the hydrogen from atmospheric effects, but acts as a sure preventive of fire risk. Both of these methods have proved easy of accomplishment. The exhaust of the motor has been freely discharged into a balloon containing hydrogen, without setting it afire. Experiments with the nitrogen jacket are said to have demonstrated the complete success of this method, which explains the story about the Germans using non-inflammable gas.

Bacterized Peat. The Problem in Relation to Plant Nutriton*

The attempts that have been made in the past to increase the fertility of a soil by inoculating it with beneficial bacteria have proved abortive, probably because the investigators made use of a liquid culture medium. The remarkably stimulating effect of soil humates upon the nitrogen-fixing bacteria was established some time ago, and efforts were accordingly made to discover a solid medium rich in soluble humates.

After much searching, natural peat, transformed by subjecting it to the action of certain aerobic organisms and sterilized at 26 deg. Cent., was found to furnish the neutral medium required. The product obtained by treating peat with alkalis is also rich in soluble humates, but it is useless as a medium for the culture of azotobacter, and it does not contain the fertilizing products of bacterial activity which are found in the bacterized variety. Thus, when *Azotobacter chroococcum* was cultivated in Beijerinck's medium containing an aqueous extract of the alcohol-soluble constituents of alkali-treated peat, and of bacterized peat, the nitrogen-fixation in the latter was over seven times greater than in the former, and the nitrogen fixed both in the raw peat extract and in the alkali-treated extract was less than that which accrued in the normal culture solution. Some extensive experiments with bacterized peat were carried out in 1913, 1914 and 1915 at Kew Gardens. Eleven different sorts of garden plants were selected, and there were four series of twelve plants of each kind, three of which were potted up in loam, sand, and varying proportions of bacterized peat, and for the fourth a compost of loam, leaf-mould, and sand was used. At the end of the experiments the Curator of the gardens reported that: "In a properly constituted soil, bacterized peat is capable of working a change in its productivity which, after a long experience with plant soils and plant foods, I am in a position to say, is very extraordinary. I have never seen anything to equal it."

*Abstract of a paper read before the London Section of the Society of Chemical Industry by Prof. W. B. Bottomley, and published in the *Journal* of the Society.

The experiments at Kew led to the discovery that the water-soluble extract of bacterized peat contains a constituent of remarkable fertilizing power, which is probably allied to the animal vitamines, for, like these, it is precipitated by phosphotungstic acid and is active in very minute amounts. (For the preparation, etc., of the phosphotungstic and silver fractions of the alcohol-extract of bacterized peat and their influence on wheat seedlings see *Roy. Soc. Proc.*, 1914, 88, B, 237-247, and also this J., 1914, 975). The stimulating effect of such "auximones" (this J., 1915, 881) has been studied further on the common duck-weed (*Lemna minor*) in water culture solution. Thirty of these plants were grown in each of three dishes containing respectively, [A] 600 *c.c.* of Detmer's complete culture solution prepared with twice-distilled water, [B] the same with the addition of the decomposed phosphotungstic acid fraction of bacterized peat in the proportion of 17 parts of dry substance per million of solution, and [C] the same plus the silver-baryta fraction in the proportion of 0.35 parts per million. The number of plants was counted weekly, their area was measured or estimated, and the solutions were renewed twice weekly during 15 weeks. Owing to the rapid multiplication of the plants in [B] and in [C], they had to be divided into two on several occasions, and one-half discarded, and at the end of the experiment the number actually in the dishes had to be multiplied by 256 to obtain the number corresponding to the original thirty.

The growth was fairly uniform for the first five weeks, although from the beginning the area of the plants in [A] was much smaller than that of the plants in the other liquids. Thereafter the development of the former was much slower, and at the finish they were in a moribund condition. After 15 weeks, the number of plants in [A] was 143,104; in [B], 416,000; in [C], 299,520; and the average area of the leaves was 0.78, 3.99, and 3.37 square millimeters, respectively. That the increased surface development of the plants treated with auximones had not been obtained at the expense of the plant structure was proved by comparing the ratios of the areas of an equal number of plants in the three series with the ratios of their dry weights. The areas of one hundred representative plants in [A], [B], and [C] were as 1 : 5.1 : 4.3, and the corresponding dry weights as 1 : 7.1 : 5.7. The differences in internal structure between the control plants and those with auximones were very marked. In the former the air-spaces were large and the individual cells small, the nuclei were ill-developed and nucleoli were not observed; in the latter, the tissue was compact, the cells large, the protoplasm dense, and the large nuclei contained a well-defined nucleolus. It is suggested that the specific function of auximones may be to stimulate the nutrition of the cell nucleus.

Bacterized peat is essentially a humus manure, and it cannot be expected to give striking results when applied to soils already rich in organic matter. Thus, at the Midland and Dairy Institute, a dressing of 7 cwt. of bacterized peat per acre gave no results on wheat, hay, and potatoes, as the land had also received 15 tons per acre of farm yard manure. On the other hand, large-scale experiments on land at the Hampshire County Council Farm Institute, Sparsholt, Winchester, which had previously borne potatoes, and had only received dressings of superphosphate and ammonium sulphate at the rates of 2 and 1 cwt. per acre respectively, gave most encouraging results with potatoes when dressed with 15 cwt. per acre of bacterized peat. Seven different varieties of potato were grown, and in every case an increase over the control field was observed. These increases were very great —88.3 per cent and 91 per cent—in two cases, and the average crop increase was 2 tons 12 cwt. per acre. The price of bacterized peat is expected to be about £2 per ton.

Cactus Makes an Excellent Cattle Food

The feeding of cactus or prickly pear is purely a local matter. Its growth is confined to the coastal region of Texas, Louisiana, and Florida, the southern half of California, and the southern portion of Arizona and New Mexico.

In those sections the wild cactus, prickly pear, or tuna has for years been used very successfully in the wintering of stock. The tuna is covered with very sharp thorns and cattle will not eat it freely unless the thorns are singed off. Gasoline torches are used for singeing the spines. Where cactus is relatively thick one man can singe the spines from enough prickly pear to feed 400 to 500 beef cattle a day.—*Report 112, U. S. Dept. of Agriculture.*

Optical Stress Analysis*

A Practical Application of the Method to Modern Engineering Problems

The constantly extending use of reinforced concrete is compelling engineers to consider some exceedingly complicated problems in elasticity, owing to the fact that with this material the joints and connections between the different parts of a structure are almost invariable of very great rigidity. It is, in fact, generally considered advisable to make the work as monolithic as possible. Of course, so far as considerations of safety are concerned, it is usually quite permissible to neglect the stiffness of the joints, since the uncalculated secondary stresses which may then exist are nefer dangerous. At the worst a joint may crack and open, but this will merely reduce the actual condition of the structure to a closer agreement with what was assumed as a basis for calculation.

The drawbacks to this procedure are two. In the first place, it becomes difficult to compare one structure with another of somewhat different design, since the calculated stresses in the two cases may not bear the same proportion to the actual stresses. It may accordingly be illegitimate to assume that because the one structure, built to a certain calculated stress, has proved satisfactory, an entirely different type of structure built to the same calculated stress will also be satisfactory.

In the second place, by making due allowance for the stiffness of the joints and for the flange effect of the roadway, a very considerable saving in material may be effected. This, as M. Rabut has most strikingly shown, is true even in the case of metallic bridges, and the consideration applies with even more force to structures of reinforced concrete.

Consider, for example, such a bridge as that illustrated in Fig. 1, which represents a reinforced concrete bridge of 95 meters span built across the Rhone at Balme. Here it is obvious that the effect of the roadway is greatly to enhance the strength of the arch, but it is by no means a simple matter to compute just what this effect is worth.

The complete solution of the problem by the method of least work is no doubt theoretically feasible to a high degree of precision, but the arithmetic involved would be of the most appalling character. In the present case the designer, M. Rabut, turned the difficulty by assuming the structure as a whole, roadway and arch ring included, to form a single arched rib with a center line intermediate between the upper surface of the roadway and the intrados of the arch. Much judgment is, however, needed to locate this center line quite satisfactorily.

In the end it was decided to check the results thus obtained by making a glass model of the structure, and determining the stresses in it by means of polarized light. This work was carried out by M. Mesnager, who has described his methods in *Annales des Pont et Chaussees*, Fasc. iv., 1913, to which we are indebted for much of what follows.

When a beam of plane polarized light is passed through a homogeneous transparent medium, it is quite unaffected, issuing from it as it entered, and remaining still a beam of plane polarized light, which can be quenched by a nicol prism appropriately adjusted. If now, the transparent material be strained, rendering it no longer homogeneous it does affect a beam of plane polarized light, which in general it breaks up into two beams of light polarized at right angles to each other, and the new planes of polarization may make any angle whatever with the original plane. Hence a nicol set so as to quench the light when the transparent material was unrestrained, is, in general, unable to do so when the original homogeneity of the material is destroyed by straining it. There are, however, two exceptional cases. If a principal axis of the strain coincides with or is at right angles to the original plane of polarization, the light is unaffected by passing through the material, and is accordingly quenched by the nicol just as before.

Fig. 2 represents a glass strut subjected to an eccentric load. In this case the plane of polarization of the light was parallel to the direction of the stress, and the consequence is that most of the body of the strut, as viewed through the nicol prism, remains as dark as it was before the stress was applied. This shows that throughout most of the body of the specimen the stress is parallel to the axis. It will be seen, however, that just in the neighborhood of the point of application of the load light managed to get through. This is due to the fact that there is always a complicated distribution

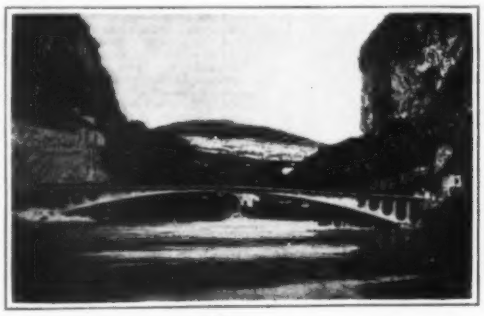


Fig. 1.

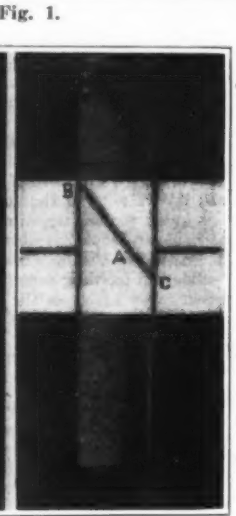
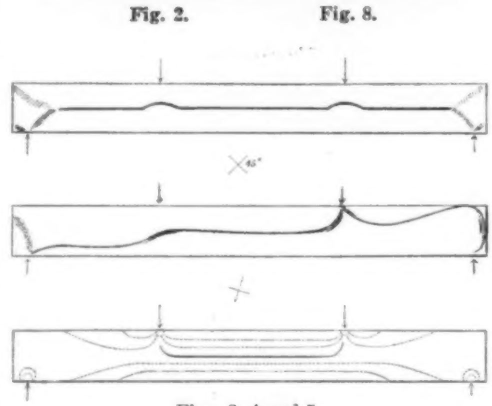
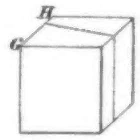


Fig. 2. Fig. 8.



Figs. 3, 4 and 5.



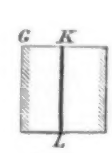


Fig. 6. Fig. 7.

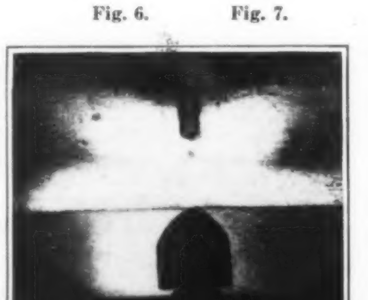


Fig. 9.

of stress in the immediate neighborhood of the point at which a load is applied. This complication however, rapidly dies away, disappearing, it will be seen, within a distance not greater than the width of the specimen. Hence, throughout the body of the specimen as a whole the stress is wholly parallel to the axis. This is, of course, the usual assumption.

Since a strained specimen remains dark at every point in which the direction of either of the principal stresses is parallel to the plane of polarization it is possible to map out the direction of these stresses for every point of the specimen. The whole series of stress lines can, therefore, be plotted as has already been thoroughly explained by Prof. Coker in *Engineering*, vol. xci., page 1.

Fig. 3 represents, according to M. Mesnager, the appearance observed when a beam loaded symmetrically with two loads is examined with light polarized at an angle of 45 degrees with the axis of the beam. In this case there is no shear in the central section of the beam, and no stress whatever along the neutral axis there, and we get, accordingly, the dark line shown. The humps underneath the arrows are due to the local effects of the applied loads, which, it will be seen, rapidly die away as the distance from the load increases. If the stress be sufficient, color effects are obtained as well as the dark line.

In the end section of the beam the neutral axis is subject to shear and to no other stress. This shear is, of course, equivalent to a tension and a compression at right angles to one another, and both inclined at 45 degrees to the neutral axis. Hence, with the nicols set at 45 degrees, the direction of the principal stresses will be parallel or perpendicular to the plane of polarization, so that this axis should appear as a dark line, and this, it will be seen, is the case. When the nicols are set at 30 degrees and 60 degrees to the axis of the beam, on the other hand, the line that shows dark has the shape indicated in Fig. 4. Everywhere along this line the principal stresses make angles of 30 degrees and 60 degrees, respectively, with the axis of the beam.

Circularly polarized light may also be used for stress analysis. This kind of light is obtained by passing a beam of polarized light through a quarter wave plate. In plane polarized light the motion of the vibrating particle is along a straight line. The quarter wave plate transforms this into a circle. When this circularly polarized light traverses a strained transparent plate, this circular path of the vibrating particle is distorted into an ellipse, which by the passage through a second quarter wave plate is transformed back into plane polarized light again. If the light received by this second wave plate is circularly polarized, one beam only of plane polarized light is produced; but when the circle has been transformed into an ellipse by passing through a strained section of the plate, two rays are formed, polarized at right angles to each other. These, on traversing the second nicol, each contribute a portion to the light that finally gets through. As these two portions have passed through paths of different lengths, optically speaking, they interfere, producing the color effects already described in *Engineering*. The color observed at any point of the specimen depends on the difference between the greatest and least stress at that point. If these two principal stresses are equal, there is no color, and the point remains dark.

Fig. 5 represents, according to M. Mesnager, the appearance of the beam already referred to when viewed by circularly polarized light. There is no stress whatever, along the center line of the mid-length of the beam, and we get, accordingly, the dark line shown. The broken lines indicate the shape of the different color bands observed. As stated, the color depends on the difference between the principal stresses. In very many cases—as, for example, at the boundary of a specimen—one of these stresses is known to be zero, so that the actual stress on the specimen can be ascertained by straining a small bar of the same material until it matches the color at the point under investigation. This plan has been followed with great success by Prof. Coker.

Another method has, however, been used by M. Mesnager, who employs a Babinet compensator. This consists of a double prism of quartz, such as indicated in Fig. 6. The two components, when placed together, form a parallel plate, but the crystal axis of the one component is perpendicular to that of the other. If polarized light be passed through this plate, we get a dark line, $K\ L$ (Fig. 7), at the point where each com-

*From *Engineering*.

Fig. 10.

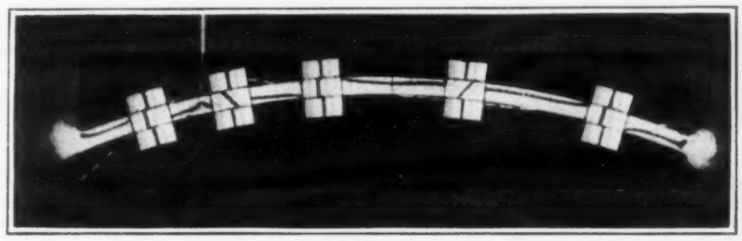


Fig. 11

ponent has the same thickness, and from this line varying color tints extend right and left to the edges of the prism. The color is the same at equal distances from the center line *K*.

These tints will each compensate for the complementary tint yielded by a strained specimen examined with circularly polarized light. The appearance observed when an eccentrically loaded strut is thus observed is represented in Fig. 8. As will be seen outside the region covered by the compensator, the specimen shows a dark vertical line, which indicates the position in which the axial stress is zero. The load being applied outside the middle third of the cross-section, the right-hand edge of the strut is in tension, and there is a neutral point indicated by the dark line as stated. Right and left of this dark line are various color tints, each of which can be compensated for by some part of the Babinet compensator placed across the specimen, as indicated. As a result a dark diagonal line shows across the specimen. As this line is straight, it shows that the stress is a uniformly varying one, thus confirming the ordinary theory.

In Fig. 9, which represents the results obtained when a notched bar is subjected to a bending test, the position of the neutral axis is shown by the dark spot a little above the notch. This being nearer the edge of the notch than to the top of the beam, proves that the stress is much higher near the notch than on the upper surface of the bar.

The Babinet compensator can be graduated to show in kilogrammes per square centimeter the stress on a standard sheet of glass, which will be compensated for at different distances from the center line of the instrument. In another form the two components of the compensator are arranged to slide one over the other by means of a micrometer screw. The relative contribution of the two components to the total thickness of the prism, opposite to a fiducial line, can thus be varied, and the screw graduated to show the stress compensated at this line with different settings.

A small arched rib of glass loaded with an isolated load, is represented in Fg. 10 as observed by circularly polarized light. The dark line represents everywhere the unrestrained layer of the rib. At the sections where this line reaches the boundary of the rib, the line of thrust on the arch passes through one or other of the limits to the middle third.

In Fig. 11 is shown the same arch photographed, along with a number of Babinet compensators. Where the dark line at the compensator is normal to the rib the thrust is also normal, and there is no shear on the sections. Elsewhere, it will be seen, the compensators indicate that the stress is a uniformly varying one which is in accord with the usual theory, when the depth of the rib is small compared with its radius of curvature.

This experiment had reference, of course, to the relatively simple case of an arched rib of uniform moments of inertia *encastré* at the ends. The calculation in such cases is fairly simple, and the experiment is, perhaps, interesting rather than instructive. When, however, we come to such a case as that of the arch represented in Fig. 1, some very sweeping assumptions have to be made in order to make the structure reasonably amenable to mathematical treatment. It was, therefore, considered desirable to confirm experimentally the conclusions arrived at in this way. An attempt to measure by mechanical means the stresses in a model proved unsatisfactory, and M. Mesnager was requested, accordingly, to investigate the stresses by optical methods. The bridge in question is of 95 meters span, and is, it will be seen, a very bold structure.

The glass model was cemented to a framework of glass as indicated in Fig. 12. The cement used was apparently some form of what is known in this country as fish glue. It was found of prime importance to make all these cemented joints between faces perpendicular to the direction of the light used in the subsequent optical analysis of the stresses. Unless this were done the shrinkage of the glue in drying gave rise to local strains, which complicated the interpretation of the experiments. This glass model and frame were mounted on a wooden frame, as shown in Fig. 14, and the load applied as indicated by means of carefully calibrated spring-balances. The stresses to be anticipated from changes of temperature were also determined by varying the span of the arch by definite amounts by means of the compression rods shown in Fig. 13.

The stresses being a maximum at the boundaries of the structure, their maximum values could be determined directly by means of polarized light. At every free boundary, in fact, one of the principal stresses is zero, so that the difference between the principal stresses which is what can be determined by optical methods, is in such regions the same as the maximum stress.

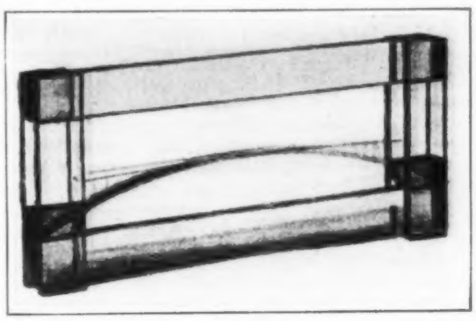


Fig. 12.

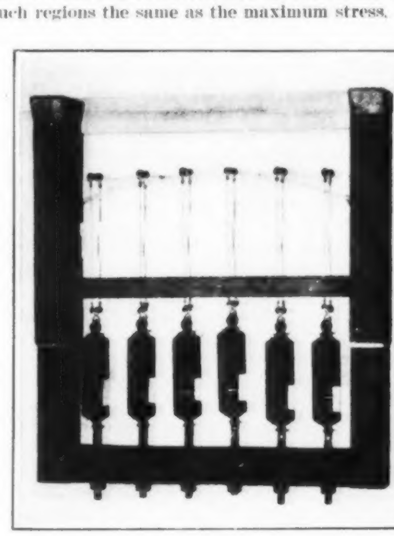


Fig. 13.

The measurements were made by means of the micrometer compensator already referred to, at twelve sections, both on the intrados and extrados of the structure, and with isolated loads, applied either singly or in combination at six different points of the roadway.

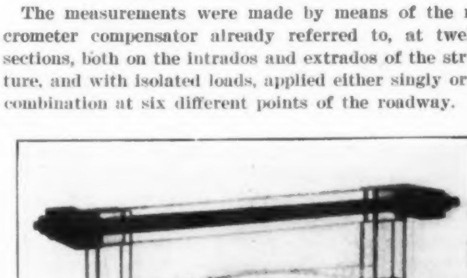


Fig. 14.

An important point established by this investigation was that owing to the assistance afforded by the roadway there was, under any load, no tension whatever on the arch ring proper.

The general result showed that the calculated stresses did not differ from the true by more than 14.7 per cent as a maximum. This figure is, M. Mesnager states, less than the discrepancies generally observed in the case of ordinary metallic bridges, in which, for example, it is usual to neglect the effect of the roadway, which really acts as so much additional flange material,, and also the stiffness of the joints. It is, he states, seldom that the difference between the calculated stresses and the actual stress falls below 25 per cent in the case of such structures, even when the calculations are made as carefully and completely as possible. Indeed, discrepancies as high as 10 per cent have been in some cases observed when the secondary stresses have been entirely neglected in the orignal calculation.

Five Years' Progress in the Industrial Fellowship System

In March, 1911, the late Robert Kennedy Duncan inaugurated the Industrial Fellowship System at the University of Pittsburgh, in the Department of Industrial Research, now known as the Mellon Institute of Industrial Research of the University of Pittsburgh. The Industrial Fellowship System represents a sane, practical plan of coöperation between industry and learning for increasing the efficiency of American industry.

The first Fellowship was founded through a grant from a baking company, which desired to improve its product. The sum of money given by this concern was used, as has been all the money which has been contributed to Fellowships, with the exception of small sums for the purchase of apparatus and chemicals, to secure the services of a man who had shown a gift for research, to devote all his time to certain problems connected with the baking industry.

During the five years which have elapsed since the establishment of the first Fellowship, 47 distinct concerns have endowed some 105 one-year Fellowships. They did this in the belief that the Mellon Institute was in position to mobilize and to concentrate all of the advantages and opportunities known to science for the solution of their particular problems. The new building of the Institute is the most complete and modern industrial experiment station in the country, and, together with the permanent organization and connection of the Institute, gives very exceptional advantages for the successful prosecution of industrial reesarch work.

The total amount of money contributed to the Institute for the five years ending March 1, 1916, was \$360,400. In addition to this sum, over \$300,000 was expended by these concerns in the construction of experimental plants and \$21,300 was awarded in bonuses to Fellows for the successful completion of problems.

During the five years the Institute itself expended about \$175,000 in taking care of the overhead expenses in connection with the Fellowships. Besides this amount, the new building and the permanent equipment of the Institute represent an investment of between \$300,000 and \$350,000.

That the results obtained under the Industrial Fellowship System of the Mellon Institute have justified the expenditure of these sums of money, both on the part of industrial concerns and the Institute itself, has been shown by the fact that during the first four years —March, 1911, to March, 1915—seven out of each ten problems assigned to the Institute for study were solved to the satisfaction of the donors. A large percentage of the Fellowships were renewed, showing the confidence which industrialists have in the Institute. Twenty-five patents have been granted to the holders of Fellowships, and there are as many more pending. Above all, some twenty new processes developed in the Institute are now in actual and successful operation on commercial scales.

At the close of the first five years of the Industrial Fellowship System at the Mellon Institute, it can be said that the plan of coöperation between science and industry which it represents has demonstrated its genuine value to American industry, and that the Institute looks forward with hope and confidence to its future development.—*From a note in the Journal of the Franklin Institute.*

Armor Plate*

History of Development and Modern Methods of Manufacture

The idea of using armor plate as a protection against gunfire arose long before it was actually put into practice. It bore at first two aspects, the protection of shore batteries on the one hand and of floating batteries on the other. The first was proposed and tested by Major-General Ford at Woolwich in 1827. A granite wall 7 feet thick was faced with two layers of iron bars 1¼ inches square, disposed vertically and horizontally; this defence was destroyed by shots from a 24-pounder gun. In America, Messrs. Stevens, of Hoboken, made some tests with 4-inch wrought-iron plates. In England experiments were carried on in the dockyards from 1846 to 1856, and in one series a 4½-inch wrought-iron plate was supported by a timber backing. In France, floating batteries propelled by steam were built for service in the Baltic during the Crimean war. The plates used were 4⅜ inches thick, 3 feet long and 20 inches wide, and they were able to resist the Russian 32-pounders. Then came (1855) the first Armstrong breech-loading gun, which heralded the new era in artillery, and the beginnings of the intense struggle between the penetrative power of guns and the resistance of armor.

THE FIRST ARMOR PLATES.

The first armored ship, as distinct from the floating batteries, was the French Gloire (1855), having iron armor plates 4¾ inches thick. The plates were rolled at Creusôt by Messrs. Schneider, who in due course (1876) also made the first steel armor plates. At the same time that the Gloire was being completed in France, the famous Warrior (1860) was being built at Blackwall with iron armor plates 4½ inches thick. Public interest was divided between this event and the mammoth ship the Great Eastern, then recently completed, and also built of iron.

Commercial wrought-iron plates are limited in dimensions because of the great cost entailed in piling and reheating and rolling. Thick armor plates, therefore, presented exceptionally great difficulties. In building them up several bars of iron were rolled 12 inches wide by 1 inch thick, and cut to lengths of 30 inches. Five of these were piled and rolled down to form a slab, and two such slabs were welded and rolled into a plate 1 inch thick, and sheared to 4 feet square. Four such plates were then piled and rolled to form one larger rectangular plate, measuring 8 feet by 4 feet by 2 inches thick, and four of these again were piled to make the final plate. In these operations from 3,500 to 4,000 square feet of surface had to be perfectly welded by the process of rolling, a marvelous testimony to the reliable character of the work and to the high mechanical skill possessed by the furnacemen of that period.

EFFECT OF PALLISER SHELLS.

The wrought-iron armor plates were absolutely invulnerable against the cast-iron projectiles of the period, until Palliser (1863) introduced methods of chilling the ogival points. His projectiles were cast-iron cylinders, rendered intensely hard and steely at the points by pouring that section into heavy chills or molds of cast-iron, while the cylindrical bodies were poured in sand. The intense rivalry which arose between wrought-iron armor and the Palliser projectiles developed in the only direction which it could take—an increase in the thickness of the plates, which in successive stages advanced from 4½ inches in the Warrior (1860) to 24 inches in the Inflexible (1880). The Repulse was provided with 6-inch armor in 1870 and the Thunderer with 12-inch in 1877; and when the Inflexible armor of 24 inches was fitted it was necessarily made up in two thicknesses.

IRON v. STEEL.

At the present time it may seem remarkable that for many years steel was regarded with much less favor as a resisting material than was wrought-iron. But the early steels were generally too hard and brittle, and so they readily became shattered. They were further of very variable quality, and plates rolled from the same heat would develop different characteristics. Precisely the same troubles occurred at the same period in connection with the employment of the new steels for steam boilers and for general constructional work. It is true also that wrought-iron revealed very variable qualities, with the exception of the best Yorkshire, which cost from £20 to £22 a ton. Though it was not easy to produce iron in thick sheets of large dimensions suitable for armor, yet wrought-iron retained its place almost unchallenged for about twenty years and this by reason of its tough qualities. Only when the Siemens steel-making process became successfully established was iron finally displaced.

The beginning of the substitution of steel armor plate for that of wrought-iron dates from about 1878, when it was still firmly believed by many that steel was unable to withstand the continuous fire of even light guns. Yet indications were not wanting then that the days of wrought-iron were nearly numbered. Numerous important experiments had been conducted on steel armor at Spezzia with the 100-ton gun. In 1877 tests had been made with steel plates by Whitworth and by Cammell. Generally the steel plates arrested the projectiles but suffered badly, being more or less cracked or shattered. The suggestion was in consequence put forward that the best solution might be found in a hard steel facing backed up by wrought-iron, which would hold the fractured parts together.

COMPOUND PLATES.

During the transitional period the "plate upon plate" or "sandwich" system of iron plating was a favorite one. The plates used were from 4 inches to 6 inches or 6½ inches thick superimposed. They were backed with teak or teak was sandwiched between them. The thinner plates were used by preference because they could be made wider than the thicker ones, though it was understood that single thick plates would offer more resistance to penetration. When the manufacture of steel improved thick plates in that material became available and then the laminated system of iron plates was abandoned.

Several curious arrangements were tried at this period. In one plates of steel and iron were both used on the sandwich system, and in another a steel plate was sandwiched between plates of wrought-iron by pouring in the molten metal when the iron plates were at welding heat, the object being to prevent the steel from opening out and cracking. Again, plugged Whitworth steel plates were employed. The plugs of hardened steel were screwed at intervals into the steel plate, partly with the object of breaking the projectile, but partly also in order to prevent the extension of any cracks that might be produced by its impact. This expedient, it may be mentioned, is one regularly adopted by boiler-makers to prevent the extension of a crack from a temporarily patched portion. Cast-iron plates, chilled on the surface, were also used. The thickness adopted in this material was about two and a half times greater than that of wrought-iron. The cast-iron resisted blows satisfactorily for awhile, especially those which struck obliquely, but later it inevitably developed fine cracks and crumbled.

Though the Spezzia trials had demonstrated the greater resisting power of steel, the material nevertheless suffered from the racking or shattering effects of the projectiles. To overcome this drawback a period of experimenting with steel faces and soft backings followed. The Polyphemus (1881) was fitted with two layers of steel plates, an inner one having a tensile strength of 45 tons per square inch, and an outer one of 60 tons per square inch. Messrs. John Brown and Messrs. Cammell, working independently, welded a hard steel face to a soft iron back, the idea being that the hard face would break up the shell, while the tougher back would be left undamaged to hold the shattered face together. The Cammell plate was made by casting a steel face on the iron back. The Brown system comprised a thin rolled steel plate for the front, an iron back, and steel cast between the two. Generally a proportion of thickness of one of steel to two of iron was adopted. The compound plates were well rolled after casting. The superiority of the compound armor over iron alone was estimated at about three to two. It therefore was adopted and used in the British navy for several years, and was in fact unrivaled until the advent of the solid steel plates produced at Creusôt by the Schneider firm, who were the first to employ nickel to increase the tenacity of the steel. But as late as 1891 compound armor was provided for the main defense of first-class British battleships, though 4-inch steel plates were being used for the secondary armor.

CEMENTATION.

Compound armor held the record against shell until the invention of Harveyized plates, introduced in the United States in 1891. A solid steel plate was cemented on the face and then water-hardened, a glass-hard face with a tough backing being thus provided. This invention at once raised the resisting power of armor by at least 50 per cent; in fact, Sir William White stated that the resistance of a 6-inch Harveyized steel plate was fully equal to that of a 10-inch compound plate.

When Harvey adopted the method of hardening the surfaces of plates with a powdered cementing material, Messrs. Schneider invented a process of cementing by means of hydro-carbon gas, followed by water hardening, and this superseded the Harveyizing system. The Harvey plate was faulty in respect of the back, not being sufficiently tough to resist the racking effects of the projectiles. The Krupp plates (1894), also cemented, gave superior results. The addition of chromium to the nickel steel, and differential treatment in hardening (variation in degree of hardness imparted to front and back), provided the necessary toughness. Nickel-chrome steel is carbonized and hardened on the outer face, gas being used for carbonizing and a water-spray for hardening. The Krupp plates were adopted by the German navy at once, but for several years Harveyized plates were retained in other navies, which, however, eventually adopted those of Krupp.

SCHNEIDER PROCESS.

Armored plates are cemented on the surface in furnaces designed for that special purpose. At the Creusôt works hydro-carbon gas is used, introduced through pipes. At a dark-red heat the hydro-carbons separate, and the liberated carbon penetrates the surface of the steel. The furnaces are fitted with movable hearths on wheels. The plates, having been already molded to their curves by templet, are placed one above another, with spaces between them, into which the gas is introduced. Each space is enclosed by a cast-steel frame inserted between adjacent plates, and rendered gas-tight with an asbestos strand. The sides of the frame are drilled to receive the rows of gas pipes. The pipes, which are water-cooled, contain passages for the gas inlet, the water outlet, and the gas escape. The furnace is fired from each side, with blast. The deposition of the carbon goes on until, by a certain appearance of the flame given by the ignition of the escaping gas, the progress of the cementing operation is estimated, when the admission of the gas is stopped for a while to permit of equal saturation of the opposed faces. It is then turned on again for a time, and these stages are repeated until the cementation is equalized and completed. The temperature of the furnaces is regulated in such a way as to effect the maximum of cementation without risk of melting the surfaces of the plates. The plates cool down in the furnaces, to be reheated and hardened subsequently. They are reheated in the vertical position in furnaces, and for the water-hardening they are suspended vertically in tanks. The walls of the tanks are drilled with holes 1½ inches apart, through which jets of water are sprinkled on the surfaces of the plates. The rate of cooling can be varied by altering the distances between the plates and walls.

KRUPP PROCESS.

The steel used for the Krupp plates is melted in open-hearth furnaces and cast in ingot molds in a pit, the contents of two or more furnaces being requisitioned. The ingots are not compressed, but are cast vertically, and are from 80 to 100 per cent heavier than the finished plate. When the ingot has cooled down to about 500 deg. Cent., it is put into a reheating furnace having a movable hearth and heated to 1,200 deg. Cent. The rolling may occupy an hour, during which the plate is turned over from time to time by hydraulic mechanism. It leaves the rolls at a temperature of about 500 deg. Cent., and after having cooled down it is sawn to dimensions and put into the carbonizing furnace. The plates are loaded on a movable hearth carried on wheels, with the faces to be carbonized set adjacent but separated by a few inches by distance pieces. The gas is introduced between the plates, the temperature raised to about 900 deg. Cent., and the action allowed to continue for a week, or two, until the carbonization has extended to about 1 inch in depth. The gas supply is under control, and the temperature is measured by pyrometers. The plates are removed from the furnace and plunged into a tank of oil, and are afterwards reheated and quenched in water. They are thus rendered tough and fibrous throughout. Any necessary bending is then done in hydraulic presses. To harden the carbonized surface, the plate is put into a furnace, laid on sand, and protected with bricks, leaving only the carbonized face uncovered. When this face is heated to about 850 deg. Cent. the plate is removed and the face is hardened by directing a number of water jets upon it. The center of the plate, therefore, retains its fibrous condition,

*Engineering Supplement of the London Times.

while the back, being much cooler when sprayed, is only moderately hard. This is termed "differential treatment." Afterwards the edges are milled, and the bolt holes are drilled and tapped in the rear face.

The beginnings of the manufacture of armor plate by Messrs. Vickers date from 1888. The firm submitted a solid plate to the Admiralty, made of ordinary steel 10½ inches in thickness and containing 0.34 per cent of carbon. It resisted both Palliser and Holtzer shells, which indented but could not perforate it. That success resulted in big orders from the Admiralty and the organization of a costly armor plate department. The next advance came with the nickel-steel alloy subjected to the Harvey process of carbonizing, followed by chilling of the surface. This nickel-steel cemented plate resisted the Holtzer projectiles, and for a while was invulnerable, the shells being shattered and the plates indented but never pierced. The net result was that the plates possessed twice the resistance of the steel plates of 1888. The methods employed are still essentially the same, though modified in details.

TYPES OF ARMOR PLATE.

From the foregoing it seems that armor plate may be grouped under three great types, each of which has had an actual victory, but of which only one has survived. Divested of technicalities they may be grouped as (1) the hard, rigid and brittle type; (2) the tough, yielding, homogeneous type; and (3) the type which comprises the characteristics of each—the plates of the present day. The all-steel plates represent the first, the wrought-iron plates the second, and the compound and carbonized plates the third.

Experiments have demonstrated that a large proportion of hard face to soft backing has less resisting power than the opposite condition. Captain Tresidder records experiments which illustrate this fact. Three plates were prepared exactly alike excepting in the proportional depth of face-hardening. One in which the crystalline depth of the fracture was 63 per cent of the whole was repeatedly perforated by uncapped projectiles as readily as though they had been capped. The points were not shattered, and the holes made were mostly clean and cylindrical. Another plate, in which 55 per cent of the fracture was crystalline, was perforated only by one projectile out of several. The third plate had 29 per cent of crystalline fracture, and all the projectiles were smashed against it. The explanation is that the softer unhardened portion of the plate holds up the hard face. Actually a percentage lower than 20 per cent is efficient.

CAPPED SHELLS.

When steel plates came into use the Palliser shells of cast-iron were abandoned for those of steel, hardened and toughened by the addition of chromium. The Holtzer projectiles (1886) were of this kind, and they held their place for several years, until the addition of nickel with chromium to the carbon steel of the armor baffled them. Between 1890 and 1900 the addition of a soft cap to projectiles enabled these to pierce the Harveyized plates. Without the cap the projectiles broke against the plates. After about 1904 the cap became generally adopted.

The value of a soft cap was suggested in 1877, when a chilled shot which would not penetrate a hard compound plate was able to perforate it when a plate of wrought-iron 2½ inches thick was placed in front. But nearly twenty years passed before the lesson was applied. In 1894 the soft cap was being fitted to the nose, but its full utility was not recognized until after some experiments had been made at Messrs. Vickers' range at Eskmeals in 1901 with uncapped and capped projectiles. A 6-inch hard-faced plate was attacked by 6-inch hard-faced projectiles uncapped. At striking velocities ranging from 1,906 to 2,177 feet-seconds the projectiles were broken on the face of the plate. A shot fired with a striking velocity of 2,261 feet-seconds just perforated the plate. But when a soft-capped projectile was fired at a striking velocity of 1,945 feet-seconds it perforated the plate completely and was itself unbroken. In 1902 the experiments were repeated with 6-inch capped and uncapped projectiles fired against an 11.8-inch Krupp cemented plate. Uncapped projectiles with striking velocities as high as 2,827 feet-seconds were broken without perforating. Capped projectiles at striking velocities as low as 2,799 feet-seconds perforated the plate without being themselves broken. Very many experiments of this kind demonstrated the utility of the soft cap. But the capped projectile is of service only against hard-faced plates. If the old soft plates had been still in use the hard-faced projectile would have held its own. Generally a 6-inch projectile will perforate a 12-inch plate when a velocity of 2,800 feet per second is given to it, while an uncapped shot will penetrate only three inches. A 6-inch projectile will perforate a 6-inch plate with a striking velocity of only 1,970 feet per second. The most remarkable fact is that the shell is often preserved intact, though the cap is broken into fragments.

PENETRATION.

As wrought-iron provided the material for the early armor (1864) it has been usual since to refer the penetrating power of projectiles to the thickness of wrought-iron which they pierce completely. Thus it is rather startling to find that the shell of a 12-inch gun which at 3,000 yards will penetrate 22 inches of Krupp armor would at the same range penetrate 45 inches of wrought-iron. At 6,000 yards the 12-inch shell will go through 18 inches of Krupp armor, and at the same range through 37 inches of wrought-iron armor. The present armor thus has rather over double the resistance of the earlier. Nor does this state the whole difference, because the penetrative power of the guns has been quadrupled. The 12-inch gun of 1864, with a projectile of 614 pounds and a muzzle energy of 7,195 feet-tons, could penetrate only 8 inches of wrought-iron armor at 6,000 yards range. The present 12-inch gun, with a projectile weighing 850 pounds and a muzzle energy of 53,045 feet-tons—more than seven times greater—can penetrate 9-inch Krupp armor, the equivalent of 17.5 inches of wrought-iron, at 24,000 yards, or over thirteen miles. Anything beyond 6,000 yards range lay outside the capacities of the 1864 gun. Incidentally it may be noted that the increase in muzzle energy and in velocity has flattened the trajectory or height of the curve followed by a modern projectile in flight. The length of the danger zone has increased and the angle for impact reduced. At 3,500 yards the present projectile has nearly ten times the energy of that fired from the earlier guns at the same range.

PRODUCTION OF ARMOR PLATE.

The steel for armor plates is melted in furnaces fired by gas, each of which will melt forty tons in about twelve hours. It is drawn off into ladles, transported by electric cranes capable of lifting 120 tons, and poured into massive ingot molds, some of which weigh sixty tons without the steel. Some of the ingots weigh 50 tons and are 36 inches thick. They are reheated and rolled out in an immense mill. One of these mills at Messrs. Vickers' works has rolls 36 inches in diameter and 12 feet in length. An ingot 36 inches thick can be rolled down to 6 inches within half an hour. The thickness after rolling is equal, but the edges are rough and irregular. At this stage the first portion of the cementing process is performed. The plates are laid one on top of another in specially constructed furnaces. Powdered charcoal is sprinkled between the opposed surfaces, and the plates remain in the furnaces from ten to twelve days, the temperature being regulated by pyrometers. During that period the charcoal is absorbed by the plates, increasing the quantity of carbon at and near the surfaces. This does not harden the surface of the plate, but it prepares it for the subsequent hardening which is done at a later stage, after the bending in the case of those plates which have to be curved, and after the planing off of the rough edges in the case of all plates. Both operations involve the use of much massive machinery and careful handling.

BENDING AND PLANING.

The bending is done in hydraulic presses. Messrs. Vickers have two of 8,000 tons power, which will bend plates up to 21 feet long and 11 feet wide. The pressure exerted is three tons to each square inch of the rams. Each weighs 600 tons. The bending of the thickest plates under the powerful persuasion of these presses is easily and quickly accomplished. In the next stage the surfaces are planed on machines which will carry a plate weighing thirty tons on a moving table, weighing as much, and will reciprocate it under the cutting tools, which cut in both directions. The plate moves at a rate of about eleven feet a minute. In other types of machines the plate is fixed in a pit below and the cutting tools are traversed over it. It is necessary to plane the surfaces of the plates smoothly, for, although they have been rolled and are smooth, the thicknesses are not so uniform as they should be to enable them to be fitted perfectly in their places. Afterwards the very rough and irregular edges are planed in machines of a totally different design. Many plates must have their edges beveled, and provision is made for dealing with these by means of hinged tool holders. When a large quantity of metal has to be removed the edges are cut or parted with circular saws. Even irregular edges occasion no difficulty; they are dealt with in a machine provided with a movable tool saddle, the tools being controlled by a templet of the same outline as the edge to be planed, and a guide pin working over the templet. Sometimes also such edges are slotted. Afterwards the holes have to be drilled in the faces, and screw threads cut in them; all this work must be completed before the plates are hardened. As the hardening would damage the smooth holes and the delicate screw threads, these are plugged with clay during the hardening processes. The holes at the back to receive the bolts by which the armor plates are screwed to the hull of the ship are drilled and screwed subsequently to hardening, because hardening does not affect the backs of these plates.

HARDENING.

The hardening process comprises two stages—the moderate hardening of the plate right through, which might be more correctly termed tempering, and the intense hardening of the outer face. The first is done with oil, the second with water. In the first stage the plate is reheated in a furnace to an exact temperature and dropped suddenly into a bath of cotton seed oil, large enough to temper the entire plate without becoming itself sensibly overheated. The result is that the plate is hardened or toughened throughout without being rendered brittle. It is both stronger and tougher than it was before immersion, but it would not resist a modern soft-nosed shell. Afterwards the surface, which has been saturated with carbon to a depth of from 2½ to 3 inches, is rendered of excessive hardness by a chilling process. A series of jets of cold water are directed under pressure against the highly carbonized surface, the plate having been heated first. This is continued during two or three hours, by which time the surface to a depth as far as the carbon has penetrated has become of glasslike hardness. If the process were continued until the plate had become intensely hard for its entire thickness it would be liable to crack under the impact of the shell. But with the hard surface backed up by a much greater thickness of relatively tough and soft material, the effect is identical with that obtained formerly, though much less efficiently, by the compound plates of wrought-iron faced with steel. To secure the best results large volumes of water are required, for otherwise the internal heat of the thick plate would be transmitted to the surface and cause some softening. In a plate 12 inches thick from 4,000 to 5,000 tons are discharged over the face. The pressure, too, must be sufficient to prevent steam from forming on the metal, which would reduce the chilling effect.

It is well known that when steel has been subjected to a hardening process it becomes distorted from its original shape and dimensions, and also that hardened steel cannot be shaped with cutting tools. As, therefore, the plates after hardening do not retain the exact shapes which they possessed before it, the necessary corrections are effected by grinding wheels. These also can be set to any angle in order to deal with beveled edges. After all this work has been done on the plates they are not sent to the shipyard to be put in position. They are first fitted together edge to edge in the shops, where any corrections that may be required can be made more readily than on the vessels.

The cost of making armor plates is necessarily high. The work is confined to a few firms, who alone are able to deal with it. The machinery is massive, extremely costly, and designed for dealing with the single product. It embraces everything from the furnaces and presses to the equipment of the powerful plant for cutting and grinding. No firm can face the outlay required unless government orders are guaranteed, and no firm without long experience in the work can be entrusted with orders. It is believed that armor plate is worth from £80 to £90 a ton. A test plate for experiments will cost £2,000, and be ruined with a few shots.

Effect of Light on Solid Silver Chloride and Bromide

COLLOIDAL metallic "fogs" are usually prepared by fusing salts in contact with the corresponding metals. The silver halides also form fogs when the solid salts are exposed to light. Optically clear crystals of silver chloride and bromide become more or less opaque and dark in color when exposed to a beam of light, but remain at first optically clear, the beam being invisible. Later, the surface at which the beam enters becomes brown, and particles, visible in the ultramicroscope, are formed. The particles grow rapidly, and will continue to grow if the crystal is removed from the light and heated at 350 deg. C. Heating in the absence of light does not produce particles. The growth of the particles is accompanied by a diminution of the coloration in their immediate neighborhood. The effect is evidently due to the separation of metallic silver in a colloidal form, growing in size as the illumination is continued. These facts strongly support the view that the latent photographic image consists of colloidal silver in ultramicroscopic form.—*R. Lorenz and K. Hiege, Z. anorg. Chem., J. Chem. Soc.*, 1916.

Suggested Mutual Repulsion of Fraunhofer Lines

By Charles E. St. John

THE correct interpretation of the results given by the spectroscope is so fundamental to progress in present day astronomy that every suggestion offering new points of view and avenues of approach to the problems furnished by the powerful instruments in commission deserves consideration. The spectrographs now used upon the sun yield spectra of such a scale and dispersion that minute changes in spectrum lines can be studied that were beyond the reach of the older instruments.

Changes in the relative position of spectrum lines are the phenomena most often under consideration. All astrophysicists recognize two conditions that produce displacements of the Fraunhofer lines, motion in the line of sight and differences in pressure, both capable of precise determination. Two others have been suggested, the gravitational effect of Einstein[1] and the anomalous dispersion hypothesis of Julius.[2] The former influence would displace all lines to a calculable amount and would, if found, add no serious difficulties to the solar problem. The effects of anomalous dispersion, however, would introduce an indeterminate factor into the spectroscopic problem. It becomes then a matter of prime importance to determine whether the relative positions of the Fraunhofer lines are measurably affected by this cause.

An accepted deduction from the theory is a mutual influence between neighboring lines, a quasi repulsion increasing with the proximity of the adjacent lines. The violet and red components of a close pair must then be displaced to the violet and red, respectively, in comparison with the displacement of the isolated lines of the same class. Displacements between the solar and arc lines give a direct and definite means of testing the question.

Iron, from its abundance of lines and the searching investigations given to them, furnishes the most reliable data. The wave lengths of the iron lines belonging to groups *a*, *b* and c½ of the Mount Wilson classification are independent of arc conditions.[3] These lines therefore are capable of giving results of the highest possible precision. The mean sun-arc displacement for 213 lines of these groups is +0.0039 A. Those who assign an important rôle to anomalous dispersion in the solar atmosphere assume that solar lines within 0.5 A from each other are subject to mutual repulsion. The mean displacement for 30 lines with companions at an average distance of 0.314 A to the red is +0.0042 A; for 59 lines with companions at an average distance of 0.270 A to the violet it is + 0.0040 A. The displacements for the three cases are equal within the limits of accidental error, and, within such limits, the equality shows the absence of mutual influence.

Since a detectable mutual repulsion between adjacent solar lines should increase their separation over that determined from terrestrial sources, another approach to the question is found through such a comparison. It is usually assumed that repulsion occurs between all closely adjacent solar lines. For forty-five pairs, mean separation 0.29 A, the differences $\triangle\lambda$ Sun — $\triangle\lambda$ Arc are positive for seventeen, negative for twenty-one and zero for seven lines, the mean differences being zero. It has recently been suggested[4] that repulsion is to be expected only if the line in the solar spectrum has a closely adjacent line due to another substance not present in the arc. The following data from recent determinations do not show the differences required by the theory, though the lines are due to different elements and originate in separate arcs.

λ Rowland.		$\triangle\lambda$ Sun.	$\triangle\lambda$ Arc.	$\triangle\lambda$ Sun — $\triangle\lambda$ Arc.
4058.915	Fe			
.081	Mn	.170	.173	—0.003
4226.904	Ca			
.606	Fe	.700	.710	—0.010
4315.138	Ti			
.262	Fe	.115	.115	0.000
4427.266	Ti			
.482	Fe	.215	.213	+0.002
4454.552	Fe			
.953	Ca	.399	.399	0.000
4489.911	Fe			
.253	Mn	.340	.340	0.000
5208.596	Cr			
.776	Fe	.169	.170	—0.001
5446.797	Ti			
.130	Fe	.332	.334	—0.002
Mean..........		.305	.307	—0.0018

Recently Albrecht[5] found by comparing the Rowland and International wave-lengths of iron lines that the violet and red components of a solar pair showed apparent displacements to the violet and red of 0.007 and 0.005A, respectively. He interpreted these as effects of anomalous dispersion, an interpretation accepted by Julius, who says,[6] "Only if the Fraunhofer lines are *mainly* due to anomalous dispersion will they be able to show a mutual influence of the observed kind and magnitude." The absence of mutual influence would, within the limits of error, remove any direct evidence that anomalous dispersion contributes to the production of the Fraunhofer lines.

As the Mount Wilson data for sun-arc displacements and for the comparative separation between close pairs of lines in solar and terrestrial spectra do not show the effect of mutual influence, it seems necessary to assume either that the Mount Wilson data are affected by systematic errors just sufficient to annihilate the effect of anomalous dispersion, or that the Rowland wave-lengths for lines in close pairs are systematically in error; a slight over-separation of such pairs would introduce an effect of the sign indicated by the theory. The results of an investigation upon "The Accuracy of the Measured Separations of Close Solar Pairs; Systematic Errors in the Rowland Table for such Lines" are given in a Contribution from this Observatory.[7] For pairs consisting of lines of intensities 3 and 4, with mean separations of 0.274, 0.145 and 0.075 A, the Rowland separations exceed the Mount Wilson values by 0.003, 0.008 and 0.013 A, respectively. As errors of this sign and magnitude would account for the deviations found by Albrecht, an exhaustive examination of the cases included in Albrecht's list was undertaken; details of this investigation will appear in a Contribution from this Observatory.

The wave-lengths of the one hundred and four lines used by Albrecht have been referred to those of neighboring free-standing lines. The measurements have been made by two observers upon spectrograms of a scale and dispersion that previous experience had shown were best adapted to each case. The errors found in the Rowland values are systematic and of a sign and magnitude corresponding to the Albrecht deviations. This correspondence is marked, large and small values of the one being associated with large and small values of the other. The coefficient of correlation between the two sets of observations is $+0.55\pm0.05$, indicating that the correlation is a practical certainty. No explanation of this correlation seems possible other than that the errors in the Rowland wave-lengths and the Albrecht deviations are two phases of the same phenomenon, that in fact the deviations observed by Albrecht are a measurement of the Rowland errors.

Summary and Conclusion.—1. The violet and red components of close pairs of solar lines show the same displacement as isolated lines when compared with the spectrum of the arc.

2. The mean separation of close pairs in the solar spectrum is the same as that determined from terrestrial sources whether the component lines are due to the same or different elements.

3. The Rowland wave-lengths for close pairs of solar lines are systematically in error; the violet and red components being assigned values, respectively too small and too large.

4. The systematic deviations for lines with violet and red companions found by comparing the Rowland and International wave-lengths go *pari passu* with and are referable to the errors in Rowland wave-lengths. The coefficient of correlation is $+0.55\pm0.05$.

5. These systematic deviations, therefore, do not furnish evidence that the relative positions of the Fraunhofer lines are systematically displaced by mutual influence. On the other hand, the sun-arc displacements and the relative separation of the components of close pairs in solar and arc spectra indicate that, within the limits of error, evidence of mutual influence is absent from the solar spectrum, and, in so far as mutual influence is a necessary corollary of anomalous dispersion in the sun, evidence for it also is absent.

*Proceedings of the National Academy of Science.

[1]A. Einstein, *Leipzig, Ann. Phys.*, 35, 898 (1911).

[2]W. H. Julius, *Astrophys. J.*, 40, 1 (1914).

[3]*Trans. Internat. Union Co-op. Solar Res.*, 4, 74. Charles E. St. John and Harold D. Babcock, "A Study of the Pole Effect in the Iron Arc," *Mt. Wilson Contr.*, 106; *Astrophys. J.*, 46 (1915).

[4]Sir Joseph Larmor, *Observatory*, 497, 103 (1916).

[5]Sebastian Albrecht, *Astrophys. J.*, 41, 333 (1915).

[6]W. H. Julius, *Astrophys. J.*, 43, 53 (1916).

[7]Charles E. St. John and L. W. Ware, *Mt. Wilson Contr.*, —, *Astrophys. J.*—(1916).

Gas From Peat

ACCORDING to a Friesland newspaper, the municipal gasworks at Akkrum in that province are extracting gas from peat mixed with coal. It is stated that if peat alone were used the retorts would become too hot, because of the steam created by the moisture always found in peat. Accordingly the retorts are filled with two parts in weight of coal to one of peat. The peat—as well as the coal—produces about 30 cubic meters of gas per 100 kilogrammes (220 lb.), and, according to a report by the United States Consul at Amsterdam, the gas produced from this mixture is declared to be of excellent quality. The peat is entirely consumed in the process, and therefore yields no by-products, as coal does in tar and coke; but the use of peat is a great saving of coal, which is important in Holland now, where all coal, and particularly gas coal, is scarce, and has to be imported from a distance at heavy cost. Peat, on the other hand, is plentiful, particularly in Friesland, and is dug in the vicinity of the gasworks.

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